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ELECTRON MICROPROBE MINERAL ANALYSIS GUIDE

Roy W. Brown
Lockheed Engineering and
Management Services Co., Inc.
Planetary and Earth Sciences Dept.
Lyndon B. Johnson Space Center
Houston, Texas   77058

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15. Supplementary Notes

Presented as a laboratory guide to X-ray mineral analysis using the electron microprobe.

16. Abstract

Electron Microprobe Mineral Analysis Guide is a compilation of X-ray tables and spectra recorded from various mineral matrices. Spectra were obtained using an Applied Research Laboratories (A.R.L.) electron microprobe, model EMX-SM equipped with LiF geared, curved crystal X-ray spectrometers, utilizing typical analytical operating conditions: 15 Kv acceleration potential, 0.02 micro-Ampere sample current as measured on a clinopyroxene standard (CP19). Tables and spectra are presented for the majority of elements, fluorine through uranium, occurring in mineral samples from lunar, meteoritic and terrestrial sources. Tables for each element contain relevant analytical information, i.e., analyzing crystal, X-ray peak, background and relative intensity information, X-ray interferences and a section containing notes on the measurement. Originally intended to cover silicates and oxide minerals the tables and spectra have been expanded to cover other mineral phases. Electron Microprobe Mineral Analysis Guide is intended as a "spectral base" to which additional spectra can be added as the analyst encounters new mineral matrices.

17. Key Words (Suggested by Author(s)) X-ray, electron microprobe, quantitative mineral analysis	18. Distribution Statement

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PREFACE

The object of this report is to provide a laboratory guide of X-ray spectra
used in quantitative electron microprobe analysis of minerals. This compila-
tion of X-ray spectra covers the majority of elements encountered during mineral
analysis from the element fluorine (atomic number 9) through uranium (atomic number
92). Spectra were obtained from lunar, meteoritic and terrestrial mineral samples
using an A.R.L. EMX-SM electron microprobe. Hopefully, this report would provide
in a single source, a reasonable assessment of interference problems which
confront the microprobe analyst.

LIST OF TABLES

Introduction

Electron Microprobe Mineral Analysis Guide (EMMAG) is a compilation of X-ray tables and spectra recorded from various mineral matrices. The Guide provides for each element complete documentation of the spectrum in the area of the selected peak and records optimum positions in the X-ray continuum for the measurement of background, and lists interferences, with both peak and background measurements, that may be encountered in mineral analysis.

Initially EMMAG was directed toward silicate and/or oxide mineral analysis and the X-ray lines listed in each table reflect both this and the emphasis of our work which at that time was primarily on lunar samples. To make the guide more general, other mineral matrices have been added as analytical problems arose. Deciding which X-ray lines to include is difficult, at times subjective, and very much dependent on my knowledge of mineral matrices and on the accuracy of the intensity information listed in "X-ray Emission and Absorption Edge Wavelengths and Interchange Settings for LiF Geared Curved Crystal Spectrometer" by E.W. White and G.G. Johnson, Jr., 2nd edition. All of the X-ray line information, i.e., wavelength, KeV, order of reflection (N), intensity (I), etc. is derived from this source. There are bound to be errors of omission in striving to list only the X-ray lines one is most likely to encounter. EMMAG is a guide to X-ray interference and background problems. In laboratory usage it is best kept in a looseleaf notebook and supplemented as one encounters new problems and matrices during the course of microprobe analysis. EMMAG is in part a condensation of

X-ray wavelength information contained in the White and Johnson, Jr. listing:
between the $\pm\Delta$ Bkg for $Si_{K\alpha1,2}$ are listed 156 x-ray lines - EMMAG lists only 9.
The 9 X-ray lines selected are believed to be those most likely to cause problems
during mineral analysis.

Tables

X-ray tables are listed by atomic number, i.e., information for fluorine is
listed in Table 9. In this manner other elements can be added without disrupting
the order of the guide. Each table is divided into four sections. The first
section gives the X-ray line information for the element: analytical line
($K\alpha1,2$, $L\alpha1$, $M\alpha$), analyzing crystal (LiF, ADP, PET, RbAP), spectrometer setting
for a given crystal, and background setting used in this laboratory. The next
section, Elemental Scans, lists the minerals for which spectra have been recorded
for the particular X-ray line, the wt. % of the element or oxide in the mineral
and the background setting which may vary depending on the mineral matrix. The
third section, Interferences, lists X-ray lines which occur within the $\pm\Delta$ Bkg
limits of the analysed line, the reflection order (N), the intensity relative to
the strongest line (the unresolved $K\alpha1\alpha2$), the spectrometer odometer setting for
the analyzing crystal, and the energy (KeV) of the X-ray line. The spectrometers
are the LiF geared type, i.e., with a LiF crystal in use the odometer reads
directly in angstroms. Other analyzing crystals indicate an interchange value.
The fourth section, Notes, contains comments pertaining to the interferences
which occur and how to deal with them plus additional information pertinent to
the analytical problem. Typically the use of a Pulse Height Analyzer (PHA)
is discussed, the PHA being the main form of electronic pulse discrimination
used with proportional X-ray counters.

Spectral Scans

The X-ray scans are an important part of the guide because they give relative intensities, position, and crystal line broadening effects of X-ray lines derived from various mineral matrices. Each scan was recorded on an A.R.L. EMX-SM electron microprobe in the Geochemistry Branch of the Planetary and Earth Sciences Division, Johnson Space Center. The microprobe has a 52.5° X-ray take-off angle and was operated with an acceleration potential of 15 KV and sample current of 0.02 microamperes measured on a clinopyroxene standard (CP19). Crystal spectrometers have a receiver slit width of 0.015" as measured with a feeler gage. Each scan was obtained by motor driving the crystal spectrometer at a speed of 0.02Å/min. synchronously with a Texas Instruments Servo/riter II recorder driven at 1"/min. Recorder output is then 0.02Å/inch of chart paper. Full scale intensity is either 300 or 100 cps as labeled. Due to low values for full scale intensity major X-ray peaks are typically off scale and therefore the associated peak position is not accurately determined. More important than accurate peak position is the relative position of the minor X-ray peaks, the extent of major peak tailing and the slope of the X-ray continuum which together provide information on the interferences present as well as optimum background positions. Each scan is labeled with element symbol, mineral matrix scanned, analyzing crystal utilized, counts per second (cps) full scale deflection and wt. % of element or oxide present in the sample.

Historical Note

Originally X-ray tables and spectra were produced for our laboratory use only; later on I thought they might be of interest to a wider audience. Because the initial intent of production was limited (1 copy) and the data collection time period (approximately nine years), some inconsistencies were propagated. Most notable among these is the use of subscripts. Therefore, let the reader be advised that $K\alpha1,2$ and $K_{.\alpha1,2}$ are the same X-ray line. Other inconsistencies and/or outright errors which may exist are not intentional and are solely the responsibility of the author.

Acknowledgments

FLUORINE

TABLE 9

ELEMENT: F

ANALYTICAL LINE: Kα

CRYSTAL: RbAP

SPECTROMETER SETTING: 2.8241

BACKGROUND SETTING: ±0.063

ELEMENTAL SCANS:

MINERAL		WT. %	BACKGROUND SETTING
Topaz	'	~19.0	±0.063

INTERFERENCES:

LINE	N	I	RbAP (100)	KeV
P SKα6	3	.01	2.8040	2.04
F SKα''	1	30	2.8056	0.68
F SKα'	1	35	2.8086	0.68
P SKα5	3	.01	2.8095	2.04
Co L1	1	9	2.8197	0.68
F Kα	1	100	2.8241	0.68
P SKα4	3	5	2.8251	2.03
P SKα3	3	5	2.8287	2.03
Ce MZ	1	.01	2.8287	0.68
P SKα'	3	.5	2.8353	2.02
P Kα1,2	3	150	2.8478	2.01
Ca Kβ1,3	6	15	2.8577	4.01
Dy Mβ	2	45	2.8848	1.33

NOTES: Fluorine is typically of interest in apatites, mica and topaz. Interferences are P and Ca, both major constituents of apatites. Both are higher order X-ray lines and a PHA can be used effectively to discriminate against them. From experience with topaz analysis, it is extremely important to match the standard and sample matrix as closely as possible due to uncertainties in the absorption correction.

F   topaz

RDAP 100 cps.

F   ~19 wt. %

95

2.69

2.71

2.73

2.75

2.77

2.79

2.81

FKα

2.83

2.85

2.87

2.89

SODIUM

TABLE 11
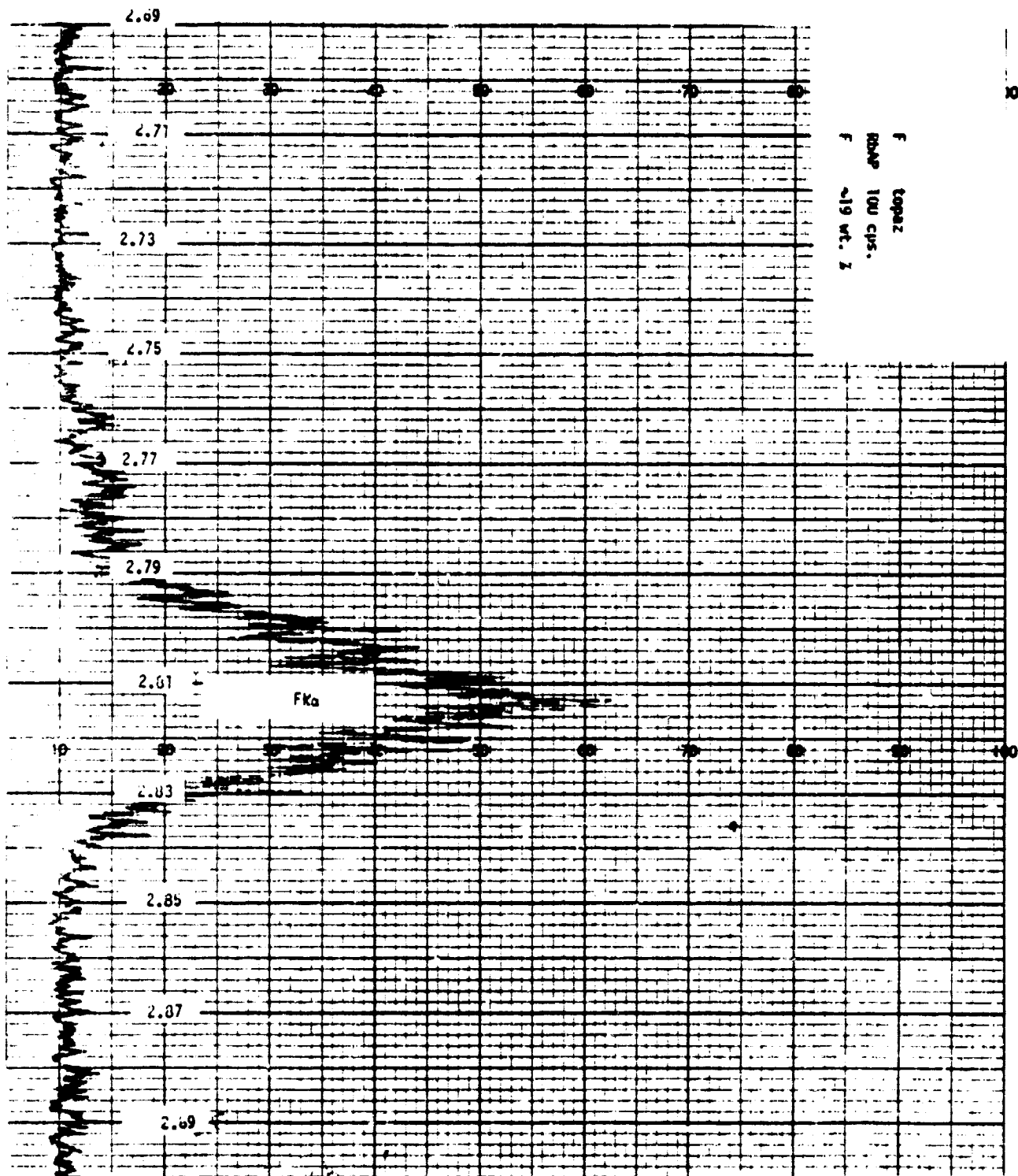
ELEMENT: Na

ANALYTICAL LINE $K\alpha 1,2$

CRYSTAL: RbAP

SPECTROMETER SETTING: 1.8360

BACKGROUND SETTING: ±0.062

ELEMENTAL SCANS:

MINERAL	WT. % OXIDE	BACKGROUND SETTING
Oligoclase	8.68	±0.062
Kaersutite	2.80	±0.062
Apatite	0.30	
Zirconium		
Zinc		

INTERFERENCE:

	LINE	N	I	RbAP (100)	KeV
P	Kβ	2	3	1.7869	2.139
P	Kβ1	2	3	1.7893	2.136
Fe	Kα1,2	6	150	1.7919	6.398
Zr	Lβ1	2	45	1.7993	2.124
Na	SKα6	1	1	1.8014	1.051
Na	SKα5	1	1	1.80f'	1.058
Na	SKα4	1	10	1.8168	1.052
Na	SKα3	1	10	1.8198	1.050
Na	SKα^1	1	3	1.8247	1.047
Na	Kα1,2	1	100	1.8360	1.041
Zn	Lβ1	1	26	1.8472	1.034

LINE	$\underline{N}$	$\underline{I}$	RbAP (100)	KeV
Ba $L\beta2,15$	5	20	1.8532	5.156
Cu $L\beta3,4$	1	1	1.8686	1.023
Zr $L\alpha1$	2	100	1.8716	2.042
P $SK\alpha4$	2	5	1.8834	2.029
P $SK\alpha3$	2	5	1.8858	2.027
Zn $L\alpha1,2$	1	100	1.8890	1.012
P $K\alpha1,2$	2	150	1.8985	2.013
Ca $KB1,3$	4	15	1.9051	4.012

NOTES: Minerals with high P concentrations might cause high background counts.

Interference with $Na_{K\alpha1,2}$ peak measurements could occur in a Zn matrix (Zn_{LB_1}). Energies of the Zn_{LB_1} (1.03 Kev) and $Na_{K\alpha1,2}$ (1.04 Kev) peaks are essentially identical and not separable by PHA methods.

Background measurements can be difficult in a high P matrix ($PK\alpha1,2$ 2nd order line) but P line should be excluded with use of PHA window. A very high Fe concentration matrix could conceivably cause a problem but could also be discriminated against with use of a PHA window. Zr has two X-ray peaks ($Zr_{L\alpha1}$, $ZrLb_1$) in this region — both should be excluded by PHA methods. Au $M\alpha1,2$ also occurs in this region but is commonly not a problem.

Na   oligoclase

RbAP   300 cps.

Na₂O   8.68 wt. %
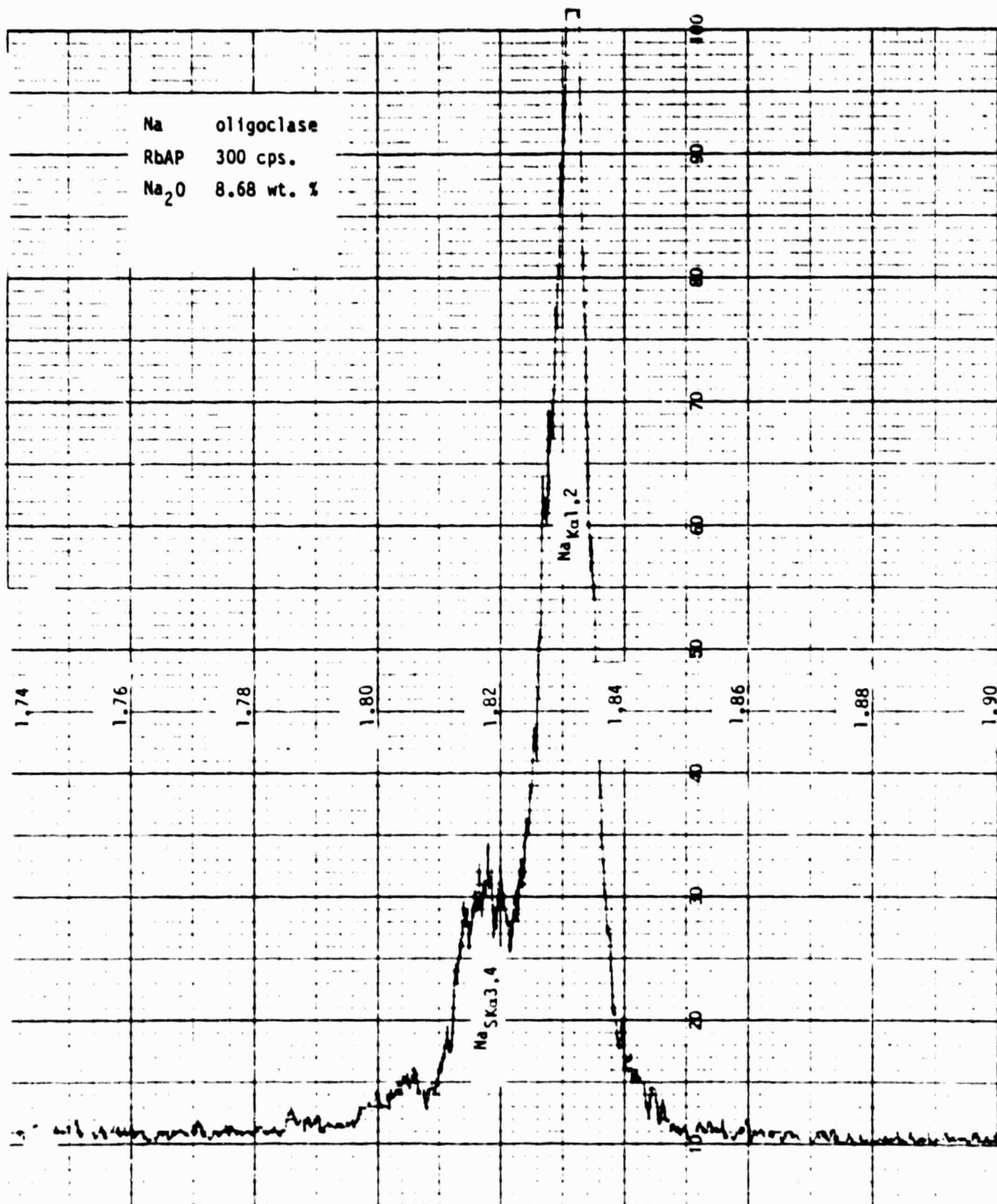
FEET LEFT

Na   kaersutite
RbAP 300 cps.
Na_2O 2.80 wt. %
FeO   11.87 wt. %

$Na_{K\alpha1,2}$

$Na_{SK\alpha3,4}$

1.75 1.77 1.79 1.81 1.83 1.85 1.87 1.89 1.91 1.93

Na   apatite, Minot Maine
RbAP 300 cps.
Na_2O 0.30 wt. % ?

85

$P_{K\alpha 1}$, 2nd

1.74 1.76 1.78 1.80 1.82 1.84 1.86 1.88 1.90

Na   Zirconium (99.9)
RbAP   300 cps.

85

1.74   1.76   1.78   1.80   1.82   1.84   1.86   1.88   1.90

$Zr_{L\beta_1}$ 2nd

$Zr_{L\alpha_1}$ 2nd

Na   Zinc (99.9)
RbAP   300 cps.

$Zn_{L\beta 1}$

$Zn_{L\alpha 1,2}$
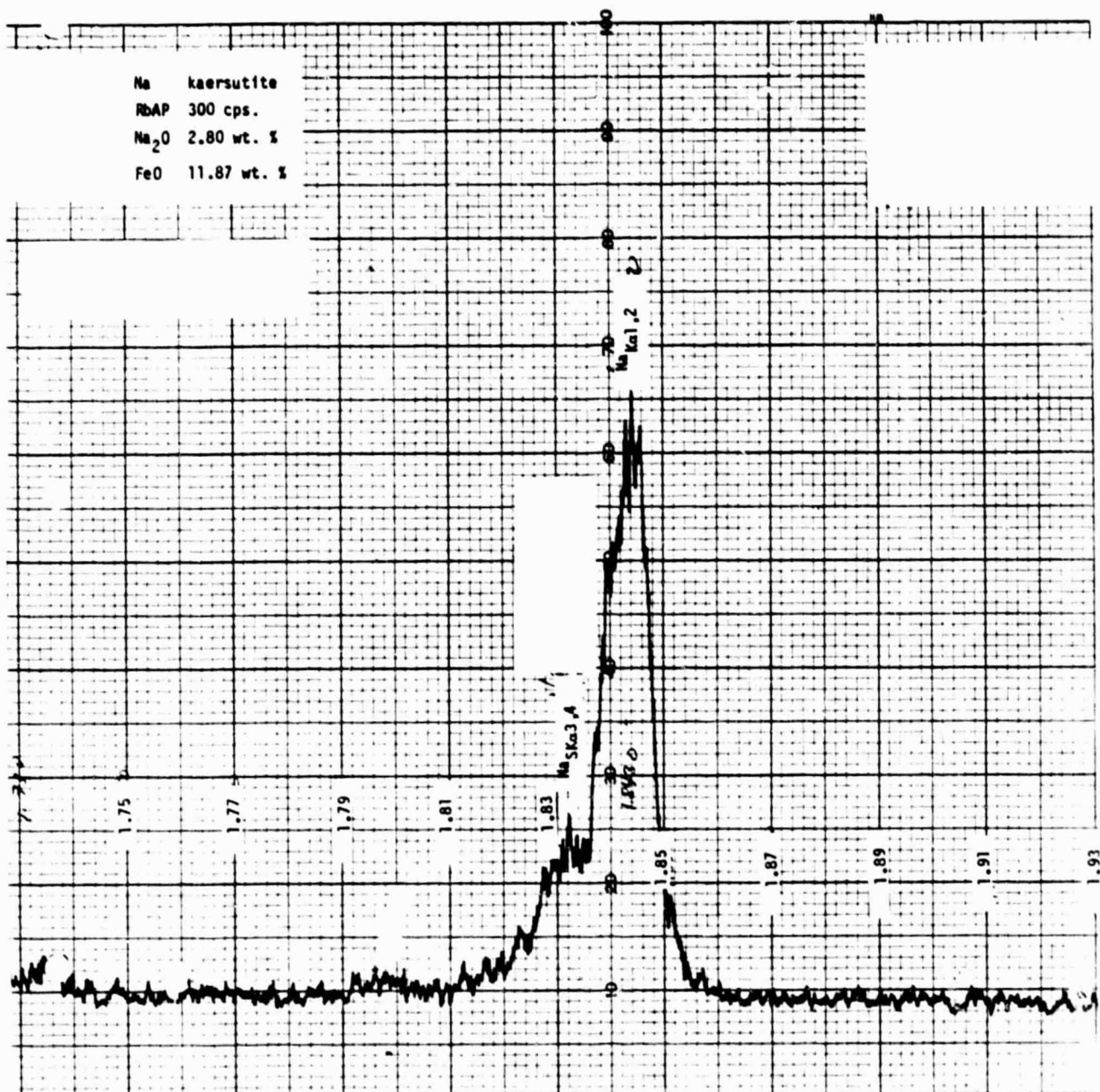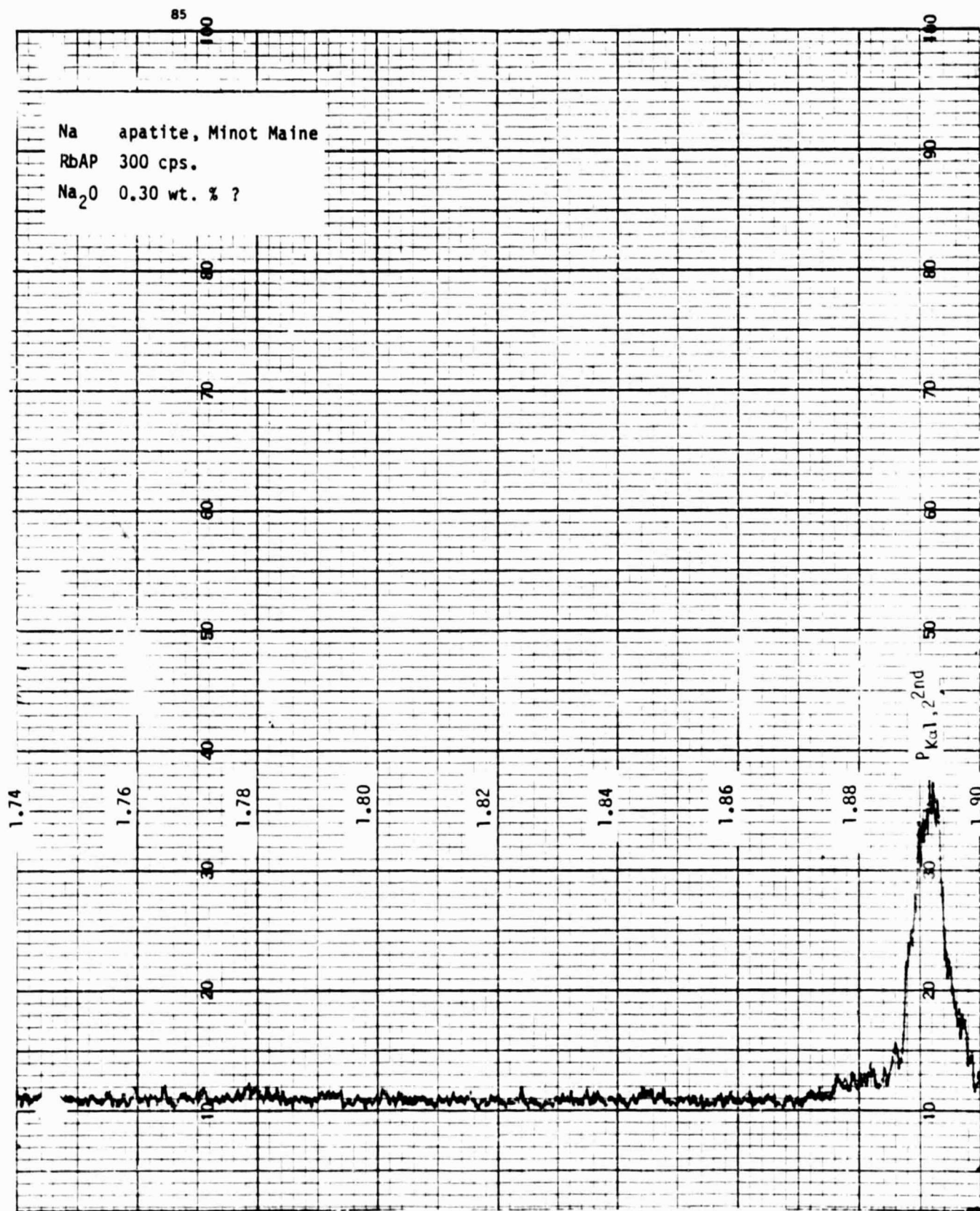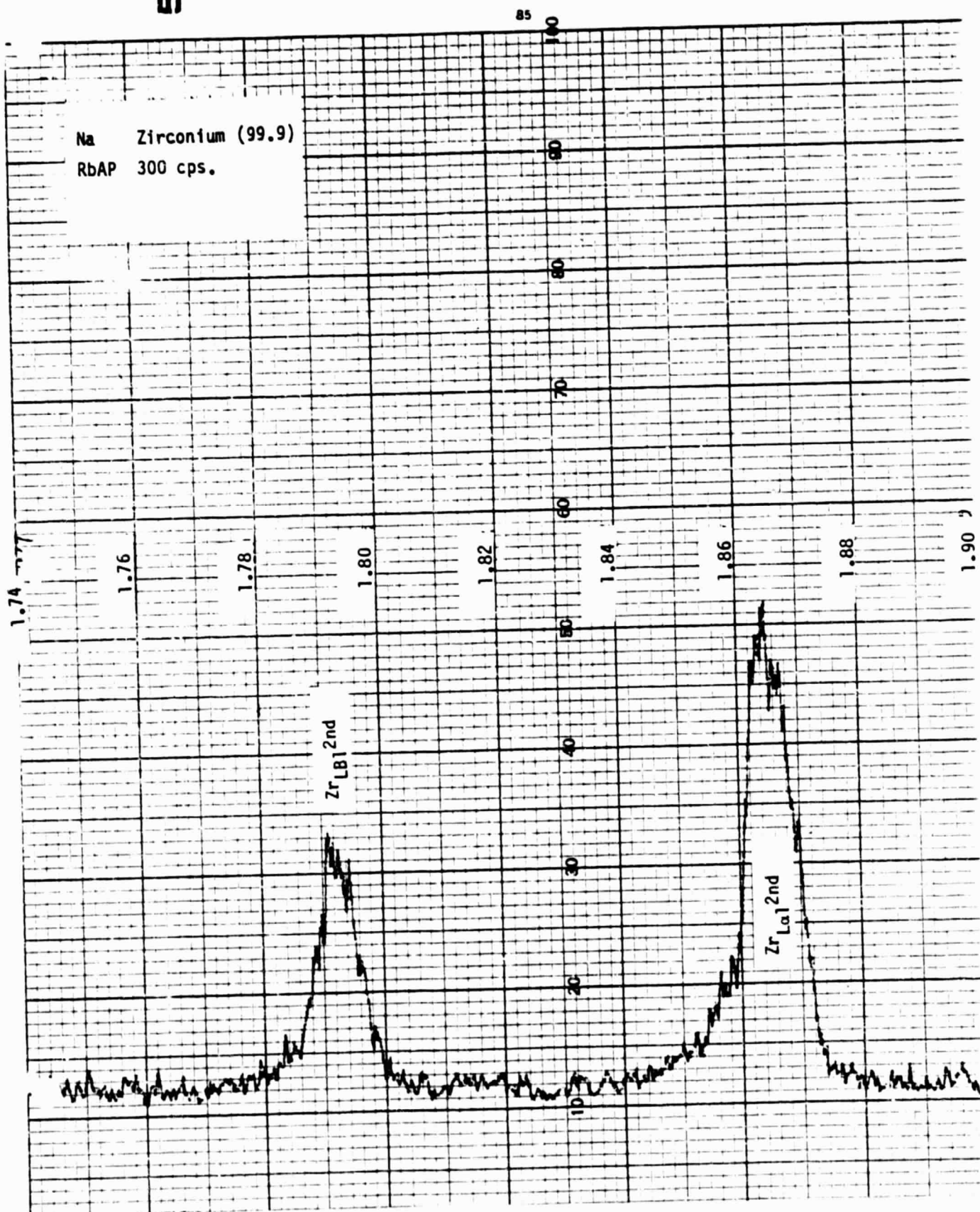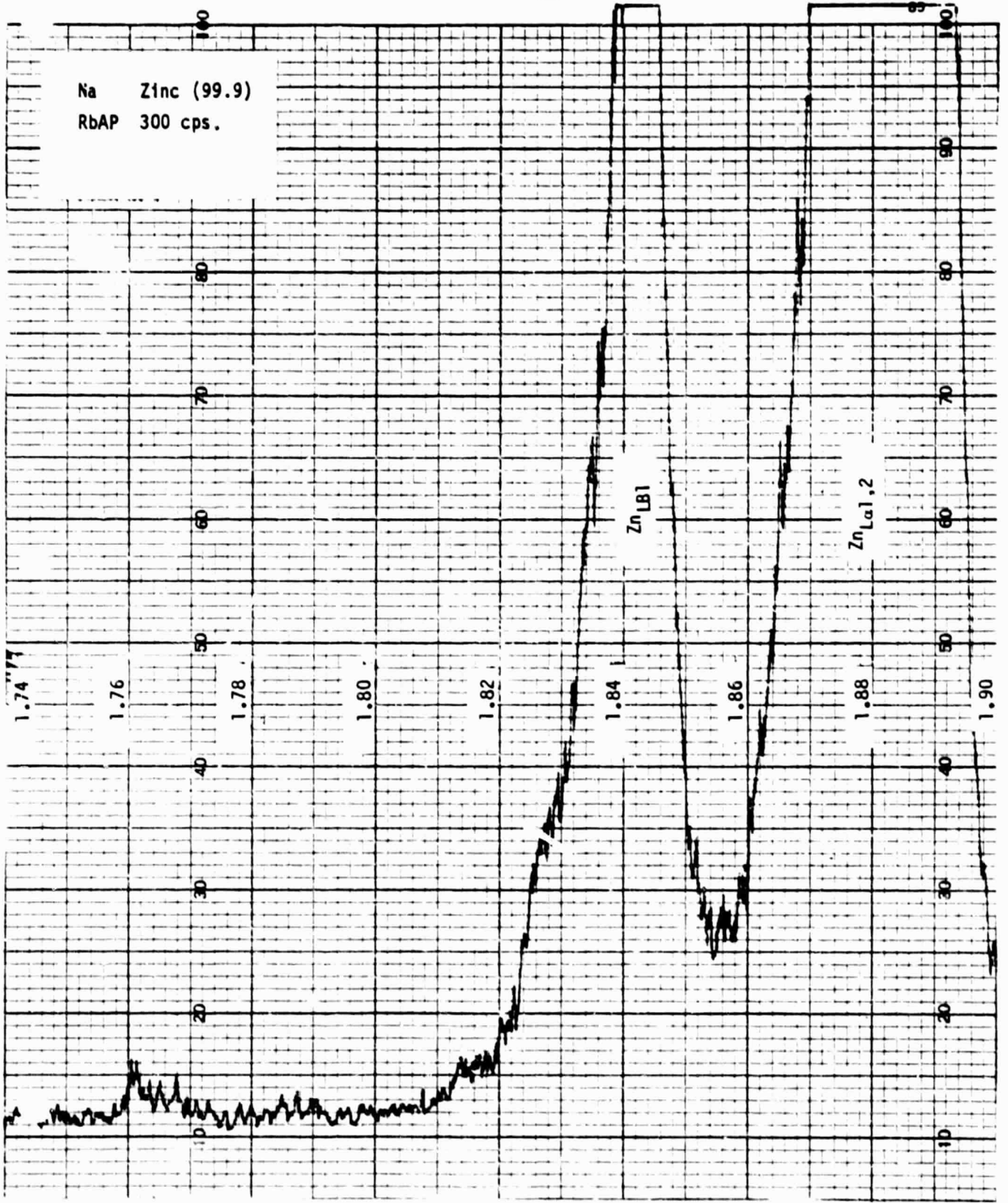
MAGNESIUM

TABLE 12 •

ELEMENT: Mg

ANALYTICAL LINE: Kα1,2

CRYSTAL: RbAP

SPECTROMETER SETTING: 1.5246

BACKGROUND SETTING: ±0.093

ELEMENTAL SCANS:

MINERAL	WT. % OXIDE	BACKGROUND SETTING
Olivine, Marjalahti	47.42	±.093
Lake Co. plagioclase	~600 ppm	
Kaersutite	11.36	±.093
Ilmenite	9.77	±.093
Chromite	8.09	±.093

INTERFERENCES:

LINE	N	I	RbAP (100)	KeV
Cr Kα1,2	4	150	1.4126	5.411
Ca Kβ1,3	3	15	1.4288	4.012
Cl Kα1,2	2	150	1.4579	2.621
Mn Kβ1,3	5	20	1.4723	6.489
Ba Lβ2,15	4	20	1.4825	5.156
Fe Kα1,2	5	150	1.4932	6.398
Co Kβ1,3	6	20	1.4991	7.648

	LINE	$\underline{N}$	$\underline{I}$	RbAP (100)	KeV
Mg	SKα4	1	8	1.5119	1.264
Mg	SKα3	1	8	1.5144	1.262
Mg	SKα^1	1	2	1.5181	1.259
Mg	Kα1.2	1	150	1.5246	1.253
Ni	Kα1,2	6	150	1.5346	7.471
Ca	SKα4	3	2	1.5431	3.715
V	Kα1,2	4	150	1.5445	4.949
Ca	SKα3	3	2	1.5447	3.711
S	Kβ$_x$	2	1	1.5487	2.468
Ti	Kβ1,3	4	20	1.5501	4.931
S	Kβ1	2	7	1.5513	2.464
Ba	Lβ3	4	6	1.5516	4.926
Ca	Kα1,2	3	150	1.5536	3.690
Ba	Lβ4	4	5	1.5756	4.851
Ba	Lβ1	4	5	1.5836	4.827
K	Kβ1,3	3	15	1.5973	3.589
Cr	Kβ1,3	5	18	1.6069	5.946

NOTES: Problems with Mg measurement might occur with a high Ca, Ni or V matrix. All 3 lines are on the high angle side of the $Mg_{k\alpha1,2}$ peak. $Ni_{k\alpha1,2}$ 6th and $V_{k\alpha1,2}$ 4th are closest to the Mg peak but do not occur in sufficient concentration in a typical silicate matrix to be a problem, however, their energies are sufficiently different from the Mg line so that they could be discriminated against with a PHA. A more common problem is a high Ca matrix (plagioclase). Fortunately the most intense Ca line ($Ca_{k\alpha1,2}$ 3rd) can also be removed with a PHA. (See scan labeled Lake Co. Plagioclase.) In choosing a background delta value, consideration should be given to the presence of numerous possible X-ray lines occurring in the $Mg_{k\alpha1,2}$ region.

Mg   Narjalahti , Olivine
RbAP   300 cps.
MgO   47.42 wt. %

1.36
1.38
1.40
1.42
1.44
1.46
$Mg_{k\beta1}$
1.48
1.50
$Mg_{k\alpha1,2}$
1.52
1.54
1.56
1.58
1.60

53
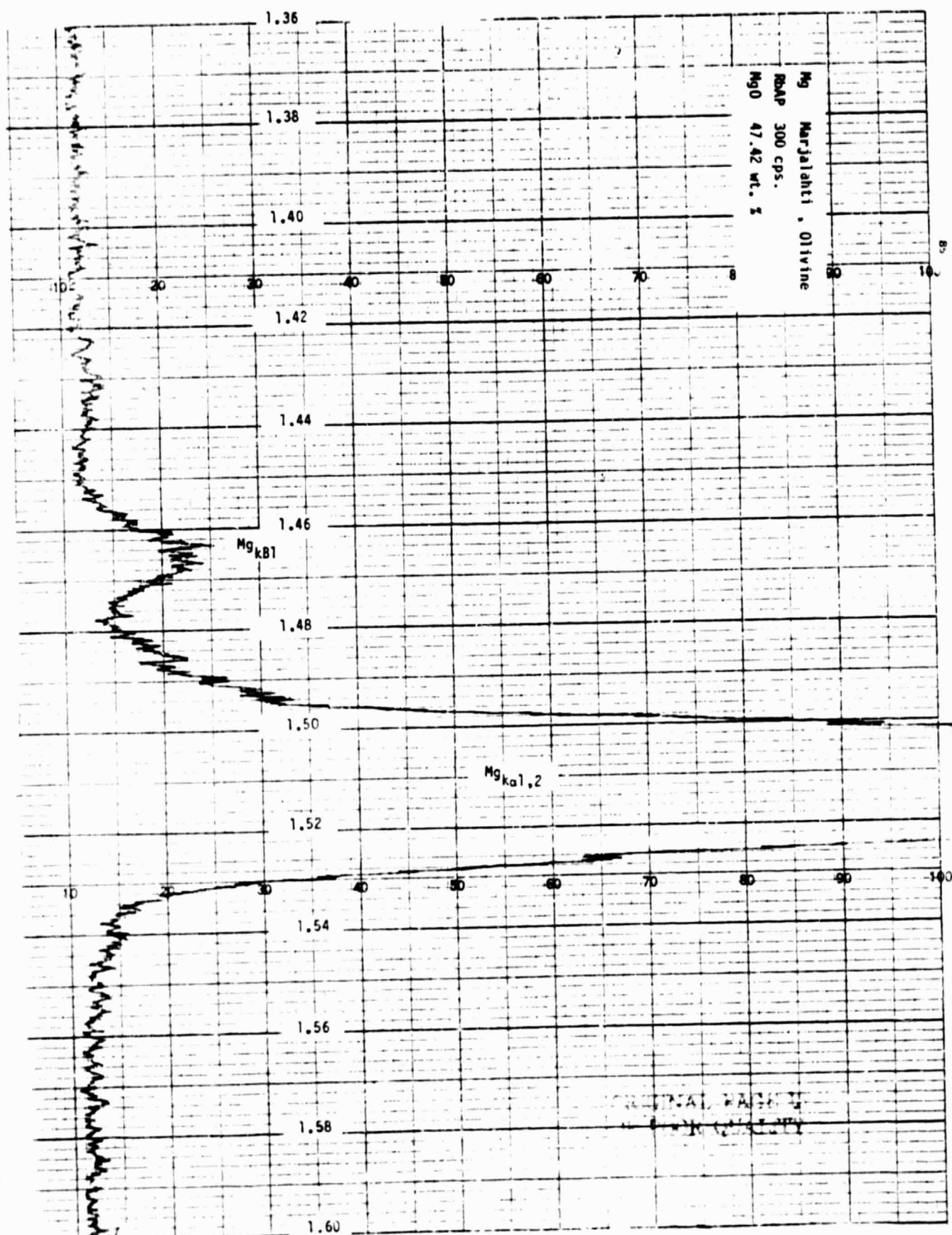
Mg   Lake Co. Plagioclase
RbAp 300 cps.
MgO ~0.09 wt. %

E = 1.30
ΔE = 1.90

1.47 1.49 1.51 1.53 1.55 1.57 1.59 1.61 1.63

Scan with PHA window (ΔE) set.

$Ca_{K\alpha 1,2}$ - 3.69 KeV

$Mg_{K\alpha 1,2}$ - 1.25 KeV

$Mg_{K\alpha 1,2}$

$Ca_{K\alpha 1,2}^{3rd}$

Scan without PHA window.

1.47 1.49 1.51 1.53 1.55 1.57 1.59 1.61 1.63

Mg   kaersutite
RbAP   300 cps.
MgO   11.36 wt. %

1.39
1.41
1.43
1.45
1.47
$Mg_{K\beta1}$
$Fe_{K\alpha1,2}$5th
1.49
1.51
$Mg_{K\alpha1,2}$
1.53
1.55
$Ca_{K\alpha1,2}$3rd
1.57
1.59
1.61
1.63
1.65

98

FEET
LEFT

1.39

1.41

1.43

1.45

1.47

Mg_{KB1}

1.49

$Fe_{Ka1,2}5th$

1.51

$Mg_{Ka1,2}$

1.53

1.55

1.57

1.59

1.61

1.63

1.65

FEET
LEFT

Mg   chromite
RbAP 300 cps.
MgO   8.09 wt. %

$Cr_{K\alpha1,2}$ 4th   1.41

1.43

1.45

1.47

1.49

$Fe_{K\alpha1,2}$ 5th   1.51

$Mg_{K\alpha1,2}$ 1.53

1.55

1.57

1.59

1.61

1.63

1.65

30 40 50 60 70 80 90 100

10 20 30 40 50 60 70 80 90 100

ALUMINUM

TABLE 13

ELEMENT: Al

ANALYTICAL LINE: Kα1,2

CRYSTAL: RbAP; ADP

SPECTROMETER SETTING: 1.2856 (RbAP); 3.1562 (ADP)

BACKGROUND SETTING: ±0.074 (RbAP); ±0.060 (ADP)

ELEMENTAL SCANS:

MINERAL	WT. % OXIDE	BACKGROUND SETTING	
		(RbAP)	(ADP)
Bytownite	32.05	±0.074	±0.060
Kaersutite	14.89	±0.074	±0.060
Chromite	12.77	±0.074	±0.060
Al-Fe Spinel	10.00	±0.074	
Ilmenite	0.26		±0.010
Armalcolite	≅1.60		±0.010

INTERFERENCES:

LINE	N	I	RbAP	ADP	KeV
V Kα1,2	3	150	1.1584	2.8438	4.949
Ti Kβ1,3	3	20	1.1626	2.8541	4.931
Ba Lβ3	3	6	1.1637	2.8569	4.926
Mn Kβ1,3	4	20	1.1778	2.8916	6.489
Ba Lβ1	3	50	1.1877	2.9157	4.827

LINE		$\underline{N}$	$\underline{I}$	RbAP	ADP	KeV
Cu	Kα1,2	5	150	1.1884	2.9175	8.040
Fe	Kα1,2	4	150	1.1946	2.9327	6.398
La	Lα1	3	100	1.2328	3.0264	4.650
La	Lα2	3	10	1.2372	3.0374	4.633
Co	Kβ1,3	5	20	1.2492	3.0669	7.648
⁻·	Kα1,2	3	150	1.2716	3.1218	4.508
Al SKα4		1	4	1.2749	3.1300	1.499
Al SKα3		1	8	1.2774	3.1360	1.496
Ni	Kα1,2	5	150	1.2788	3.1395	7.471
Al SKα^1		1	2	1.2802	3.1428	1.493
Ba	Lα1	3	100	1.2838	3.1516	4.465
Cr	Kβ1,3	4	18	1.2855	3.1560	5.946
Al	Kα1,2	1	150	1.2856	3.1562	1.486
Cu	Kβ1,3	6	20	1.2877	3.1612	8.904
Cu	Kβ3	6	6	1.2880	3.1621	8.901
Ba	Lα2	3	10	1.2882	3.1625	4.450
Mn	Kα1,2	4	150	1.2968	3.1836	5.894
Zn	Kα1,2	6	150	1.3286	3.2616	8.630
Fe	Kβ1,3	5	20	1.3539	3.3239	7.057
Co	Kα1,2	5	150	1.3799	3.3875	6.924
Ba	Lα1	4	5	1.3821	3.3931	5.53
Ni	Kβ1,3	6	20	1.3875	3.4063	8.263
V	Kβ1,3	4	20	1.4086	3.4580	5.426
Cr	Kα1,2	4	150	1.4126	3.4680	5.411

NOTES: Measurement of $Al_{K\alpha1,2}$ can be difficult due to the numerous peaks occurring in the region of the Al peak. Only one X-ray line ($Cr_{K\beta1,3}$4th) interferes directly with the peak measurement and it can be excluded with a PHA window.

$Ti_{K\alpha1,2}$3rd can also interfere with an Al determination, due to its close proxomity to the Al peak (see ilmenite scan). Fortunately a PHA window can also be used to minimize the Ti peak. Other elements occur in sufficiently low concentration in typical silicate matrices and also are high order lines and therefore less likely to present a problem.

FEET
LEFT

Al   bytownite
RAP   300 cps.
Al_2O_3 32.05 wt. %

1.17

1.19

1.21

$Al_{K\beta1}$
1.23

1.25

1.27

$Al_{K\alpha1,2}$

1.29

1.31

1.33

1.35

1.37

1.39

1.41

Al chromite
RbAP 300 cps.
Al_2O_3 12.77 wt. %

0

1.20

10 20 30 40 50 60 70 8

1.22

$Al_{K\beta1}$

1.24

1.26

1.28 $Al_{K\alpha1,2}$ $Cr_{K\beta1,3}$

98

FEET
LEFT

1.30

1.32

10 20 30 40 50 60 70 80 90 100

1.34

1.36

1.38

Al   Al-Fe spinel
RbAP   300 cps.
Al₂O₃ 10.37 wt. %

Fe$_{K\alpha1,2}$4th

Al$_{K\beta1}$

Al$_{K\alpha1,2}$

94

Al   ilmenite
RbAP 300 cps.
Al_2O_3 0.26 wt. %

$Ti_{K\alpha1,2}^{3rd}$

$Al_{K\alpha1,2}$
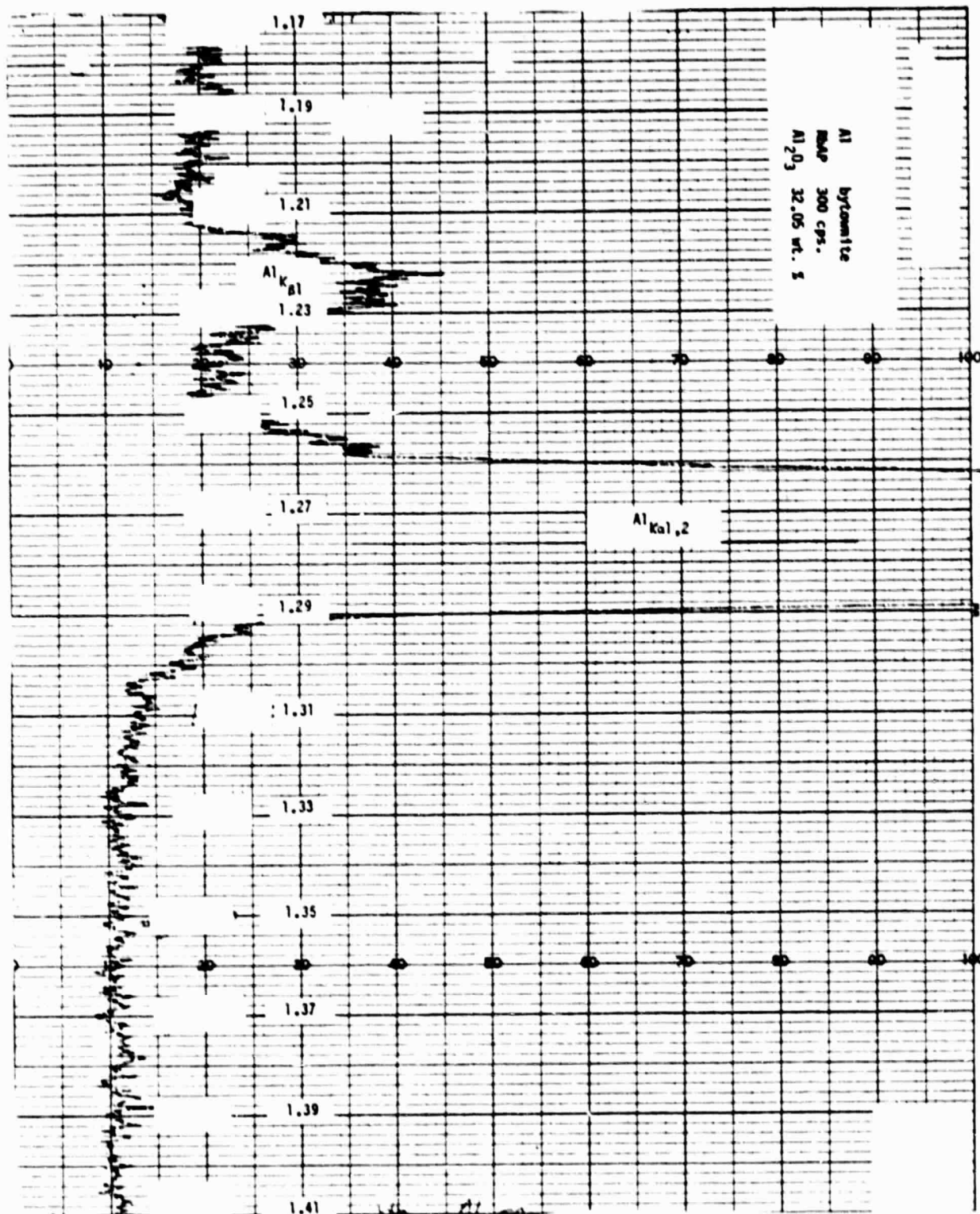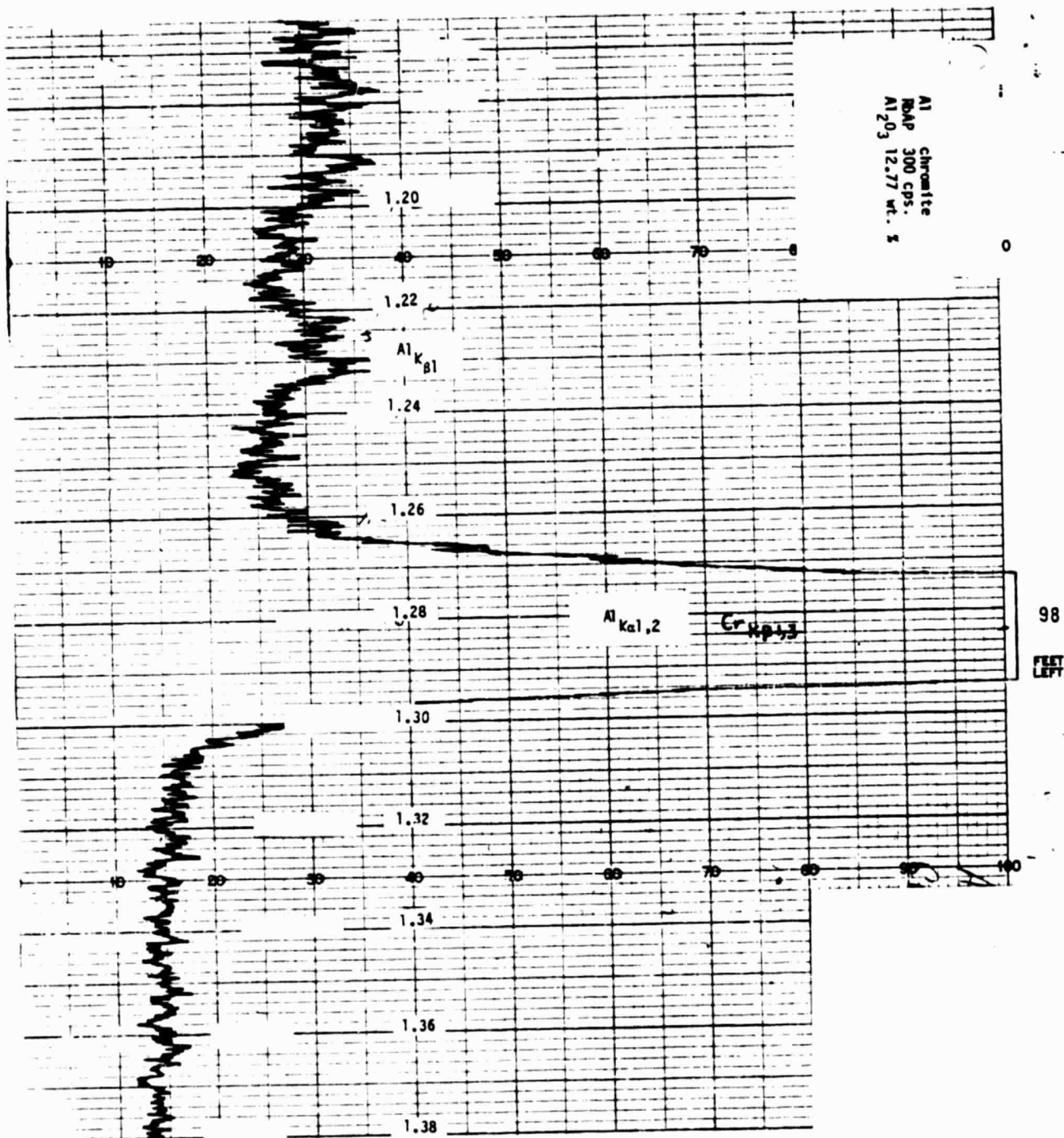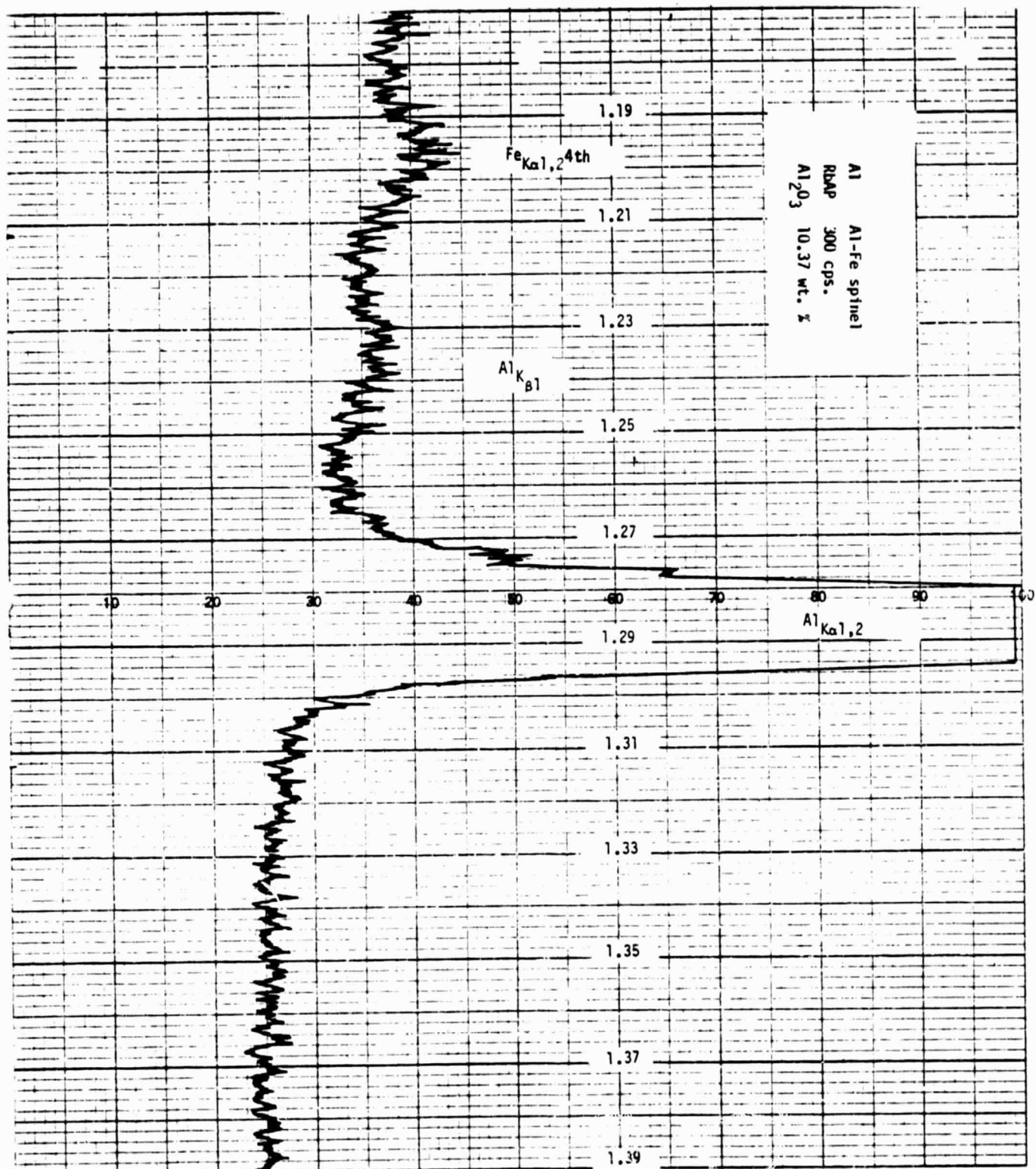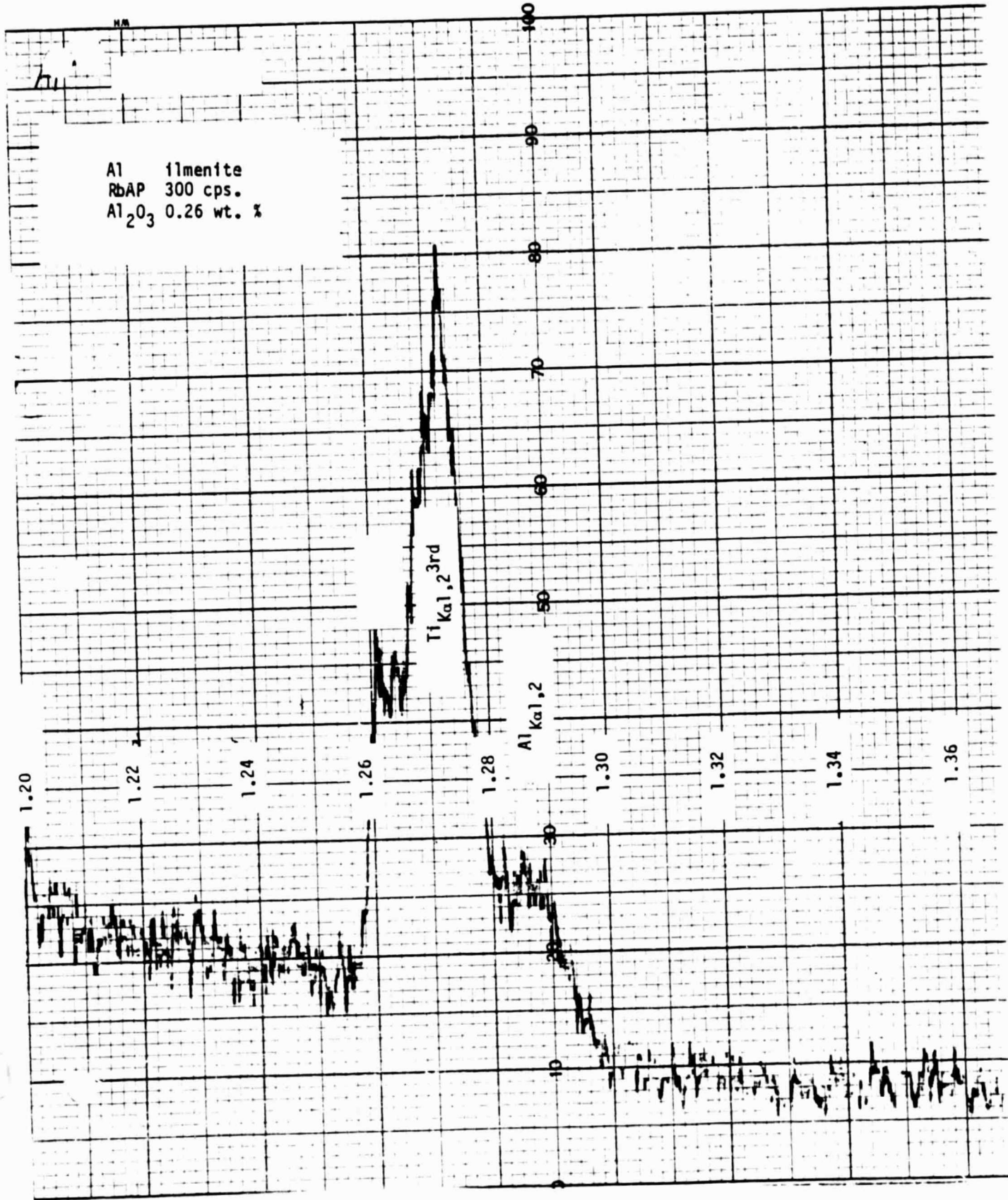
Al   kaersutite
ADP   300 cps.
Al_2O_3 14.69 wt. %

Al   bytownite
ADP   300 cps.
Al_2O_3 32.05 wt. %
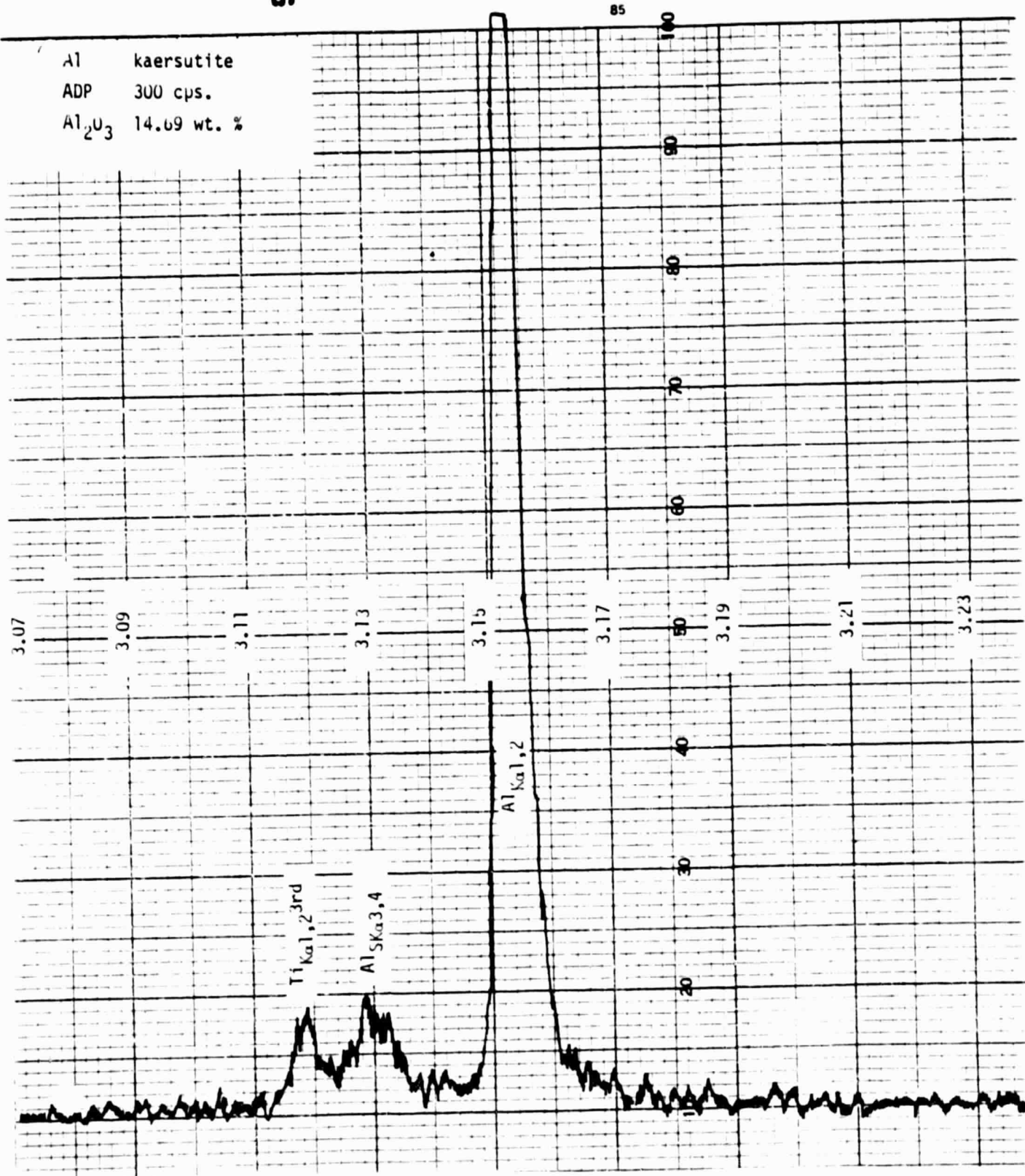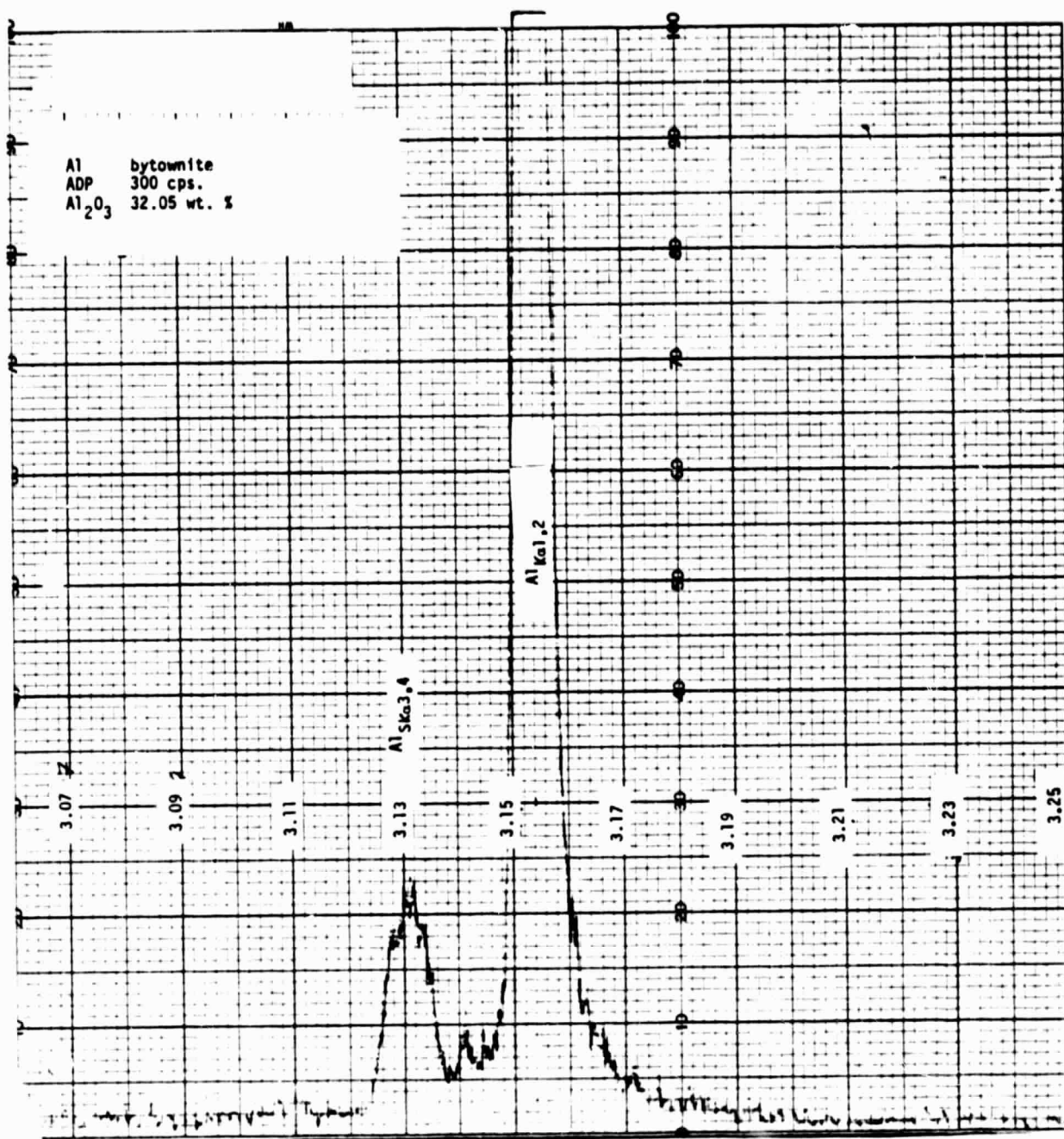
Al   chromite
ADP   300 cps.
Al₂O₃   12.77 wt. %

Al   ilmenite
ADP   300 cps.
Al_2O_3 0.26 wt. %

$Ti_{k\alpha1,2}$³rd

$Al_{k\alpha1,2}$

3.05 3.07 3.09 3.11 3.13 3.15 3.17 3.19 3.21 3.23 3.25
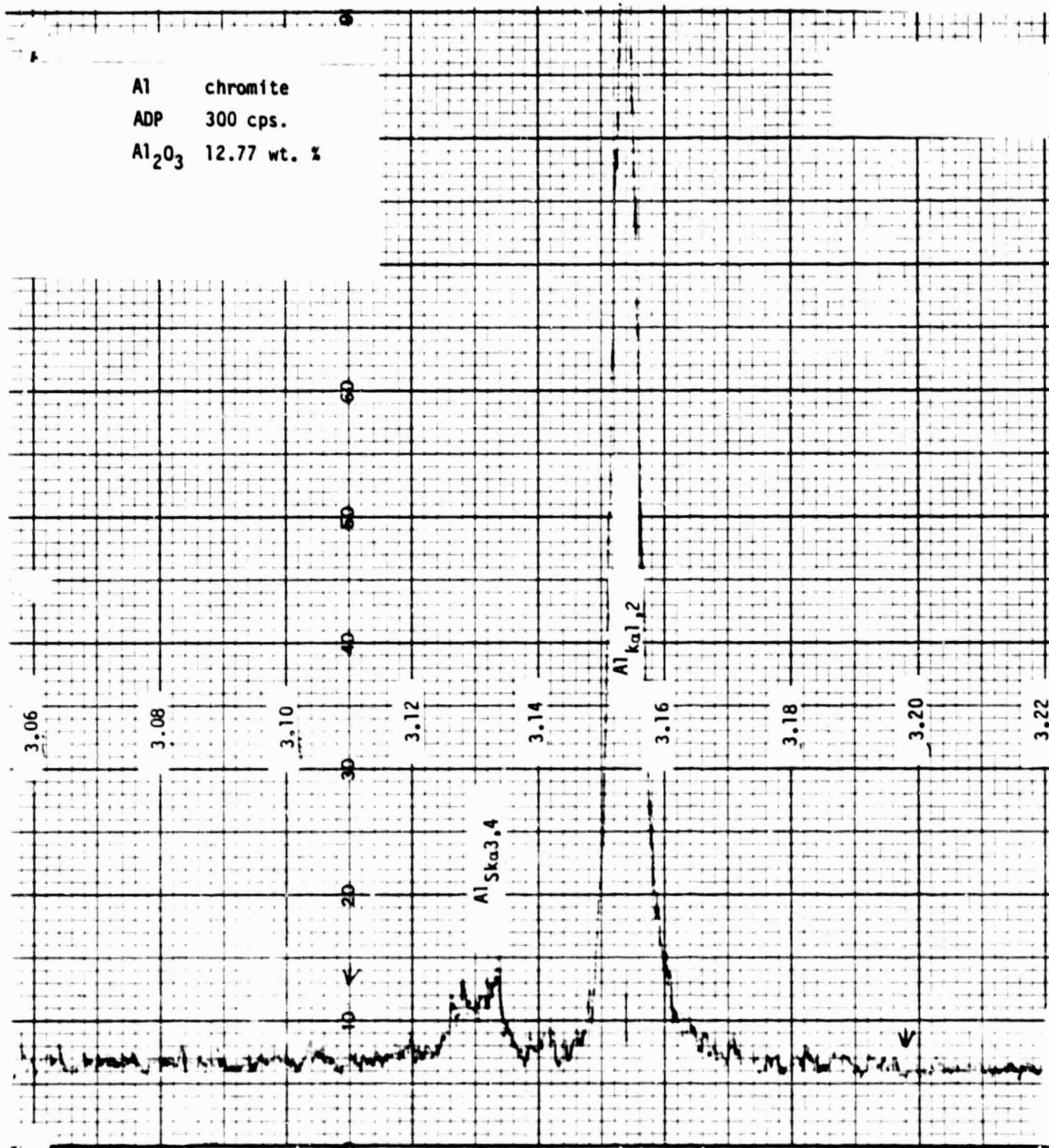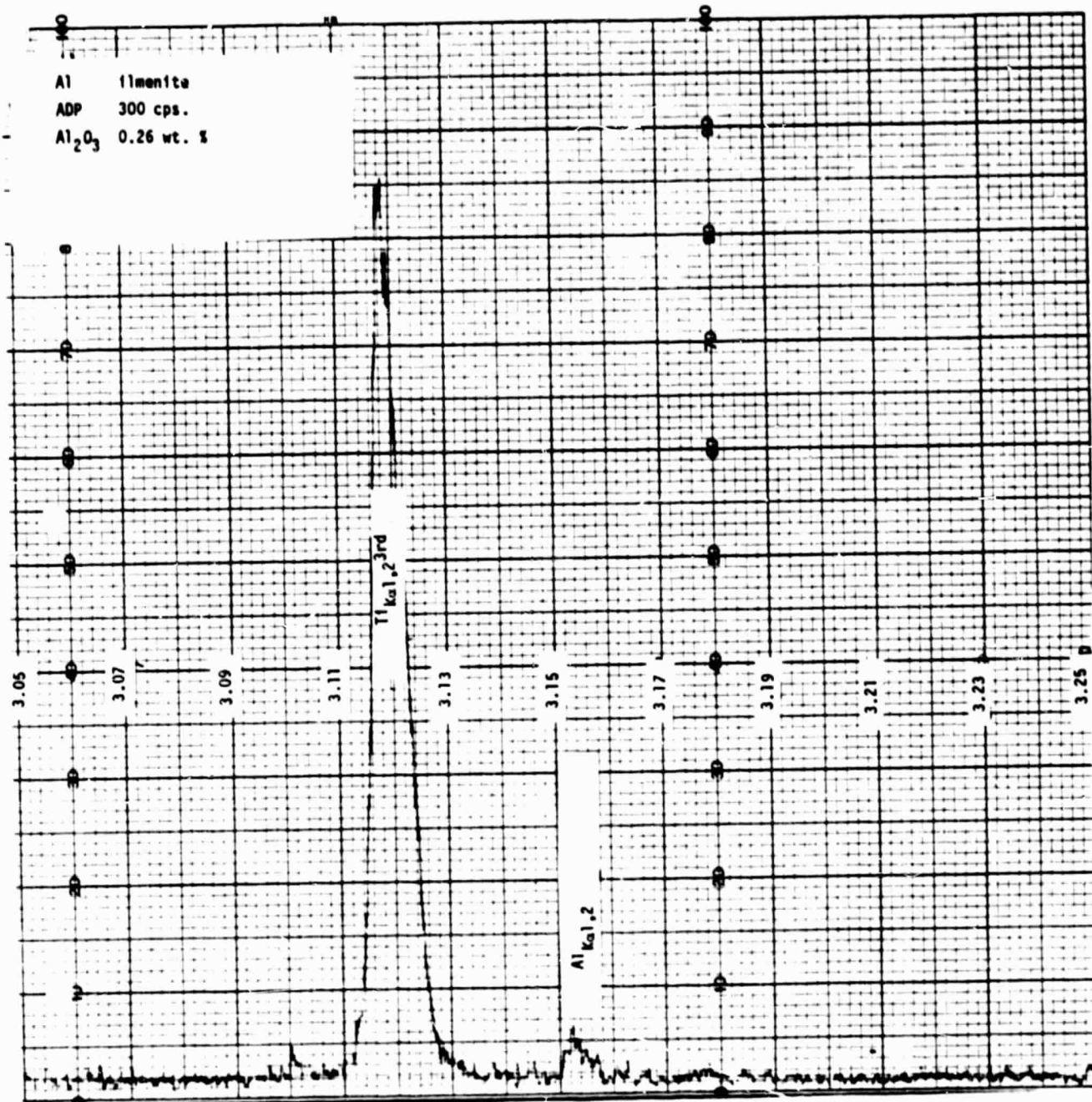
FEET
LEFT

Al   armalcolite
ADP   300 cps.
Al_2O_3 1.28 wt. %

$Ti_{K\alpha1,2}3rd$

$Al_{K\alpha1,2}$

100

90

80

70

60

50

40

30

20

10

3.07

3.09

3.11

3.13

3.15

3.17

3.19

3.21
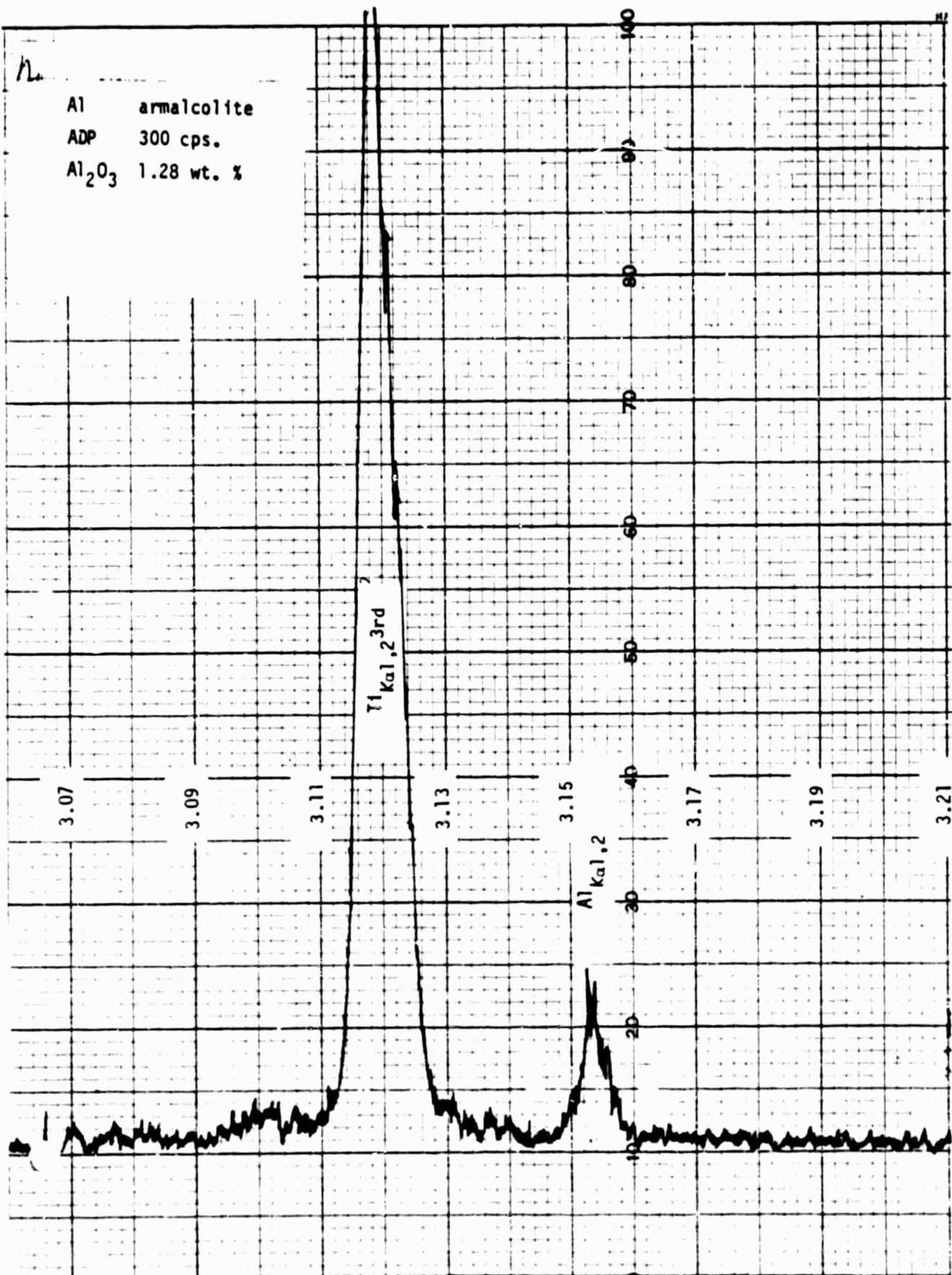
SILICON

TABLE 14

ELEMENT: Si

ANALYTICAL LINE: $K\alpha 1,2$

CRYSTAL: ADP

SPECTROMETER SETTING: 2.6969

BACKGROUND SETTING: ±0.060

ELEMENTAL SCANS:

MINERAL	WT. % OXIDE	BACKGROUND SETTING
CP19	47.44	±0.060
Fe		

INTERFERENCES:

	LINE	N	I	ADP (101)	KeV
	Fe $K\beta 1,3$	4	20	2.6591	7.057
	Y Ln	1	1	2.6644	1.761
Si	$SK\alpha 4$	1	3	2.6743	1.754
Si	$SK\alpha 3$	1	6	2.6781	1.752
Si	$K\alpha 1,2$	1	150	2.6969	1.739
	Co $K\alpha 1,2$	4	150	2.7100	6.924
	Zn $K\alpha 1,2$	5	150	2.7180	8.630
	Ba $L\beta 2,15$	3	20	2.7297	5.156
	La $L\beta 3$	3	6	2.7367	5.143

NOTE: No interference with peak measurement in typical silicate matrix. Avoid $Fe_{K\beta 1,3}$ peak when choosing background positions.

19 FF

S1   clinopyroxene (CP19)
ADP   300 cps.
SiO_2 48.39 wt. %

S1kα1,2

S1kα3

Fekβ1,3 4th

2.58 2.60 2.62 2.64 2.66 2.68 2.70 2.72 2.74 2.76 2.78

Si   Fe

ADP   300 cps.

Fe   99.9 wt.%

2.62 2.64 2.66 2.68 2.70 2.72

Fe$_{K\beta 1,3}$ 4th
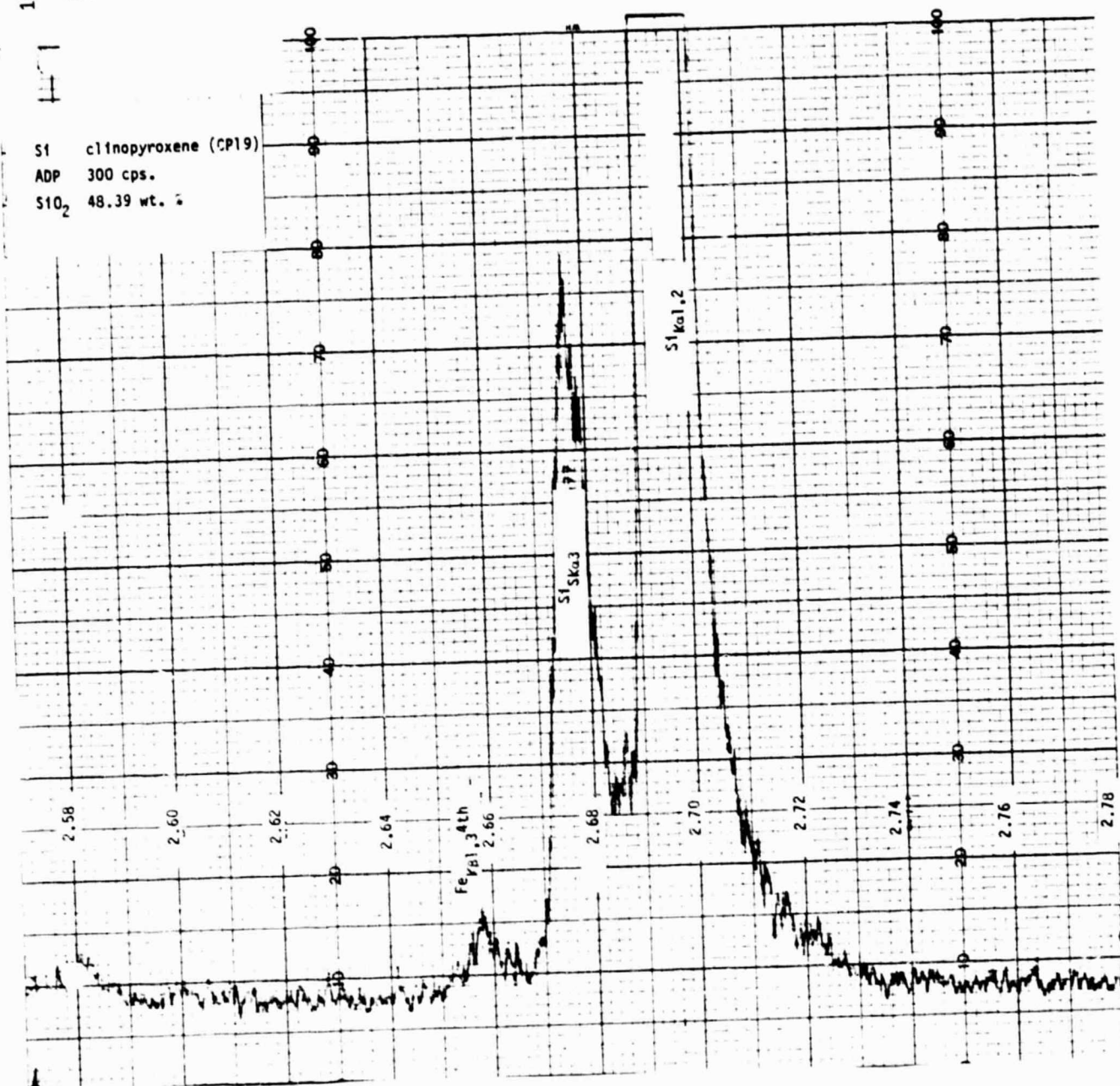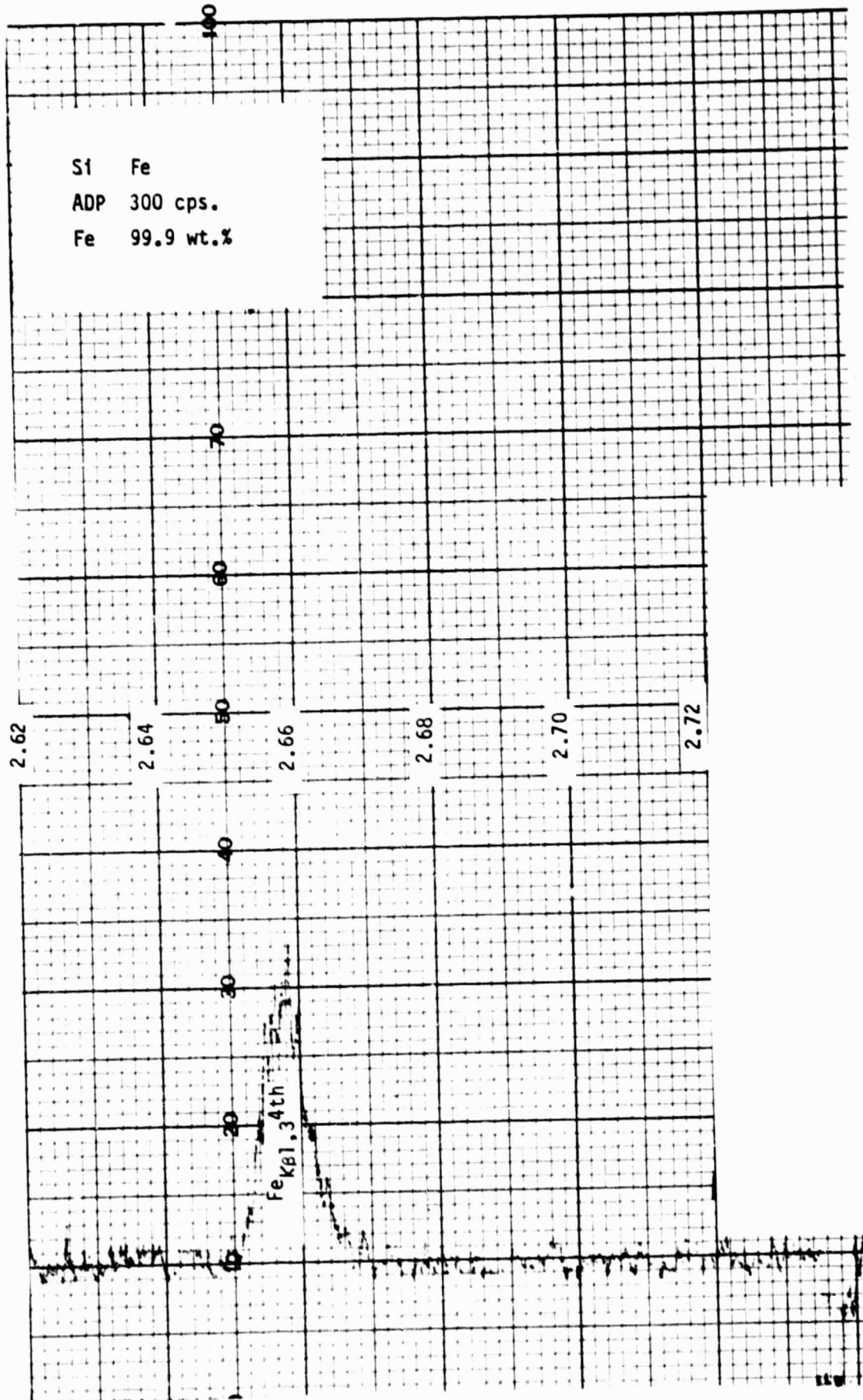
Si   clinopyroxene (CP19)
PET   300 cps.
SiO$_2$ 48.39 wt. %

TABLE 19

ELEMENT: K

ANALYTICAL LINE: $K\alpha1,2$

CRYSTAL: ADP, PET

SPECTROMETER SETTING: 1.4163(ADP); 1.7238(PET)

BACKGROUND SETTING: ±0.070

ELEMENTAL SCANS:

MINERAL	WT. % OXIDE	BACKGROUND SETTING
Orthoclase	15.36	±0.070
Kaersutite	1.59	±0.070

INTERFERENCES:

LINE	$\underline{N}$	$\underline{I}$	ADP (101)	PET (002)	KeV
Co $K\alpha1,2$	2	150	1.3550	1.6492	6.92
K SKα4	1	3	1.4065	1.7118	3.34
K SKα3	1	3	1.4080	1.7137	3.33
K $K\alpha1,2$	1	150	1.4163	1.7238	3.31
Mn $K\beta5$	2	.03	1.4359	1.7476	6.53
Mn $K\beta1,3$	2	20	1.4458	1.7597	6.49
Fe $K\alpha1,2$	2	150	1.4663	1.7847	6.40

NOTES: By using a background setting of ±0.070 the possible background interference from $Mn_{K\beta1,3}$2nd and $Fe_{K\alpha1,2}$2nd should be avoided. (See scans.)

PHOSPHORUS

TABLE 15

ELEMENT   P

ANALYTICAL LINE: $K\alpha 1,2$

CRYSTAL: PET

SPECTROMETER SETTING: 2.8364

BACKGROUND SETTING: ±0.060

ELEMENTAL SCANS:

MINERAL	WT. % OXIDE	BACKGROUND SETTING
Apatite	41.29 P_2O_5	±0.060
Schreibersite	∿15.5 % P	±0.060
Diopside		

INTERFERENCES:

	N	I	ADP (101)	PET (002)	KeV
NiKβ1,3	4	20	2.2708	2.7639	8.26
Pt Mα1	1	100	2.2884	2.7853	2.05
P SKα6	1	.01	2.2946	2.7927	2.04
Zr Lα1	1	100	2.2973	2.7961	2.04
P SKα5	1	.01	2.2991	2.7983	2.04
Zr Lα2	1	10	2.3000	2.7995	2.04
P SKα4	1	5	2.3118	2.8137	2.03
P SKα3	1	5	2.3148	2.8173	2.03
P SKα'	1	.5	2.3202	2.8239	2.02
CaKβ5	2	.01	2.3271	2.8323	4.03
P Kα1,2	1	150	2.3304	2.8364	2.01
CuKα1,2	4	150	2.3340	2.8407	8.04
CaKβ1,3	2	15	2.3385	2.8463	4.01
GeKα1,2	5	150	2.3754	2.8911	9.87
MnKα1,2	3	150	2.3877	2.9061	5.89

NOTES: The $Ca_{K\beta 1,3}$ 2nd interferes with the $P_{K\alpha 1,2}$ measurement, however, it does not usually present a problem in silicate analysis because the Ca line is a 2nd order line and requires ∿20.0 wt. % CaO concentration before the line is observed (see diopside scan). Therefore, Ca would typically only be a problem in minerals such as apatite or a high Ca glass. Where it is a problem it can be discriminated against with a properly set PHA window.

P   apatite
PET   300 cps.
P_2O_5 41.29 wt. %

50

P   schreibersite
PET 300 cps.
P   ~15.5 wt. %

$P_{K\alpha 1,2}$

$P_{SK\alpha 3,4}$

85

100

90

80

70

60

50

40

30

20

10

2.74   2.76   2.78   2.80   2.82   2.84   2.86   2.88   2.90
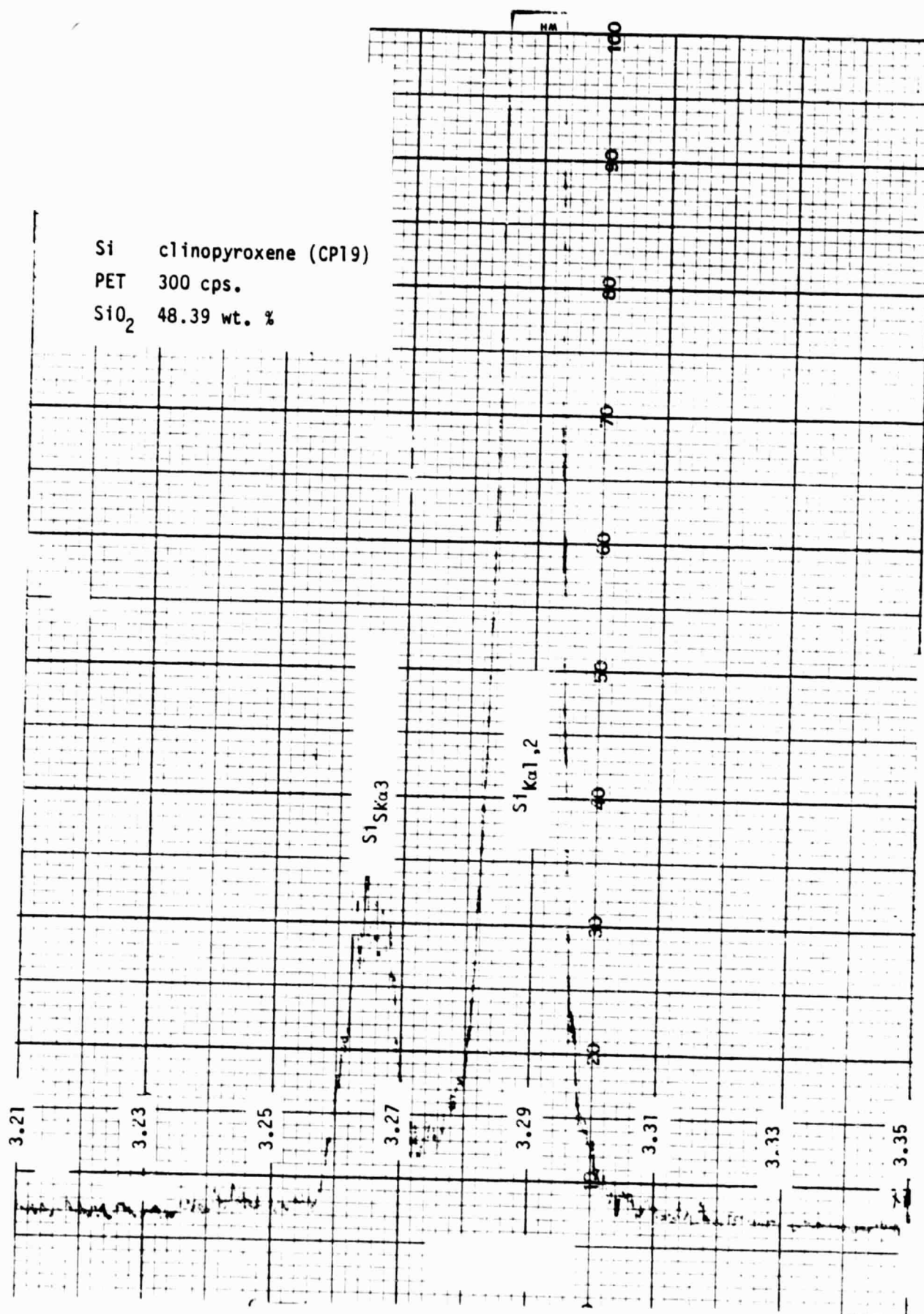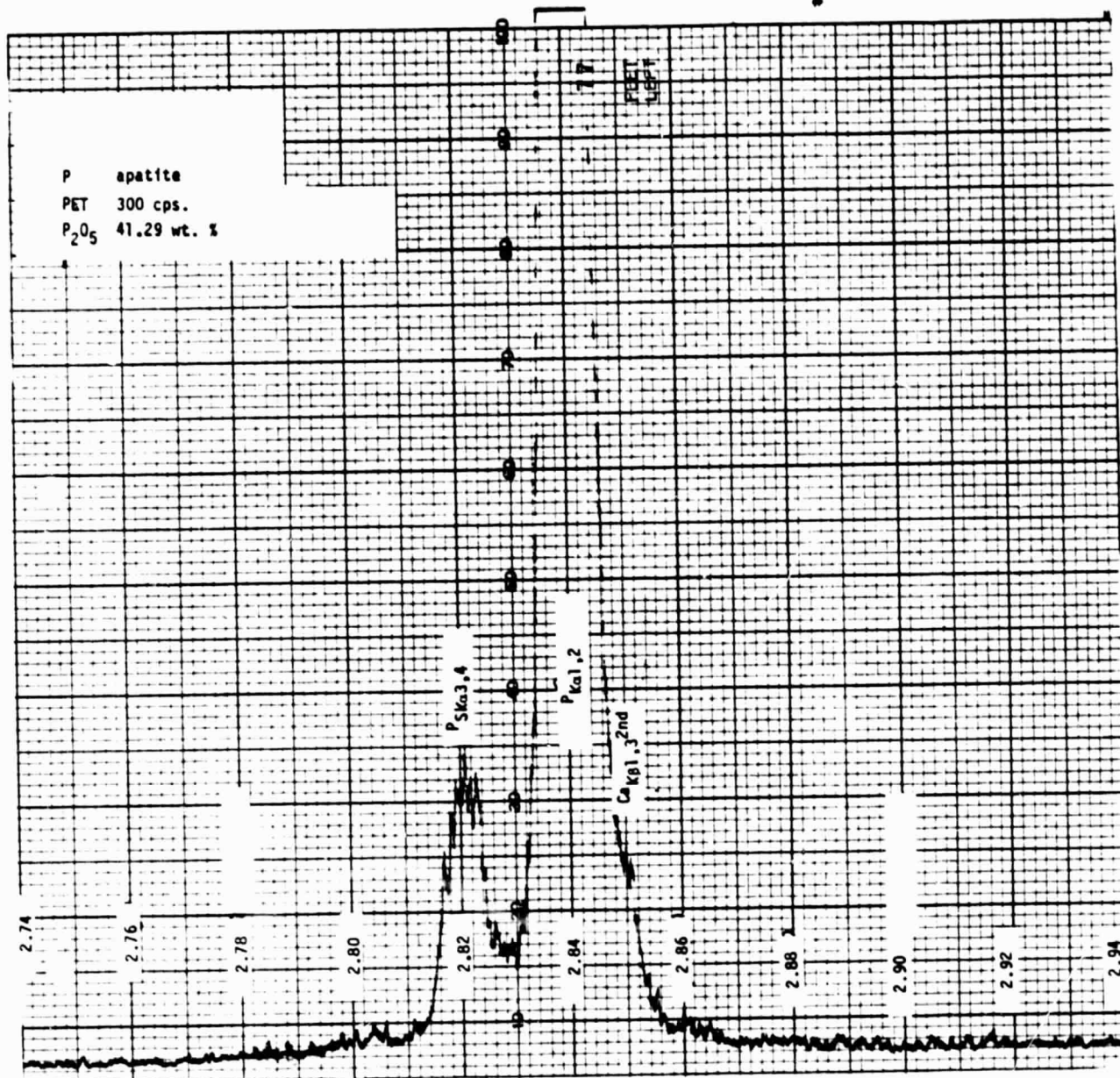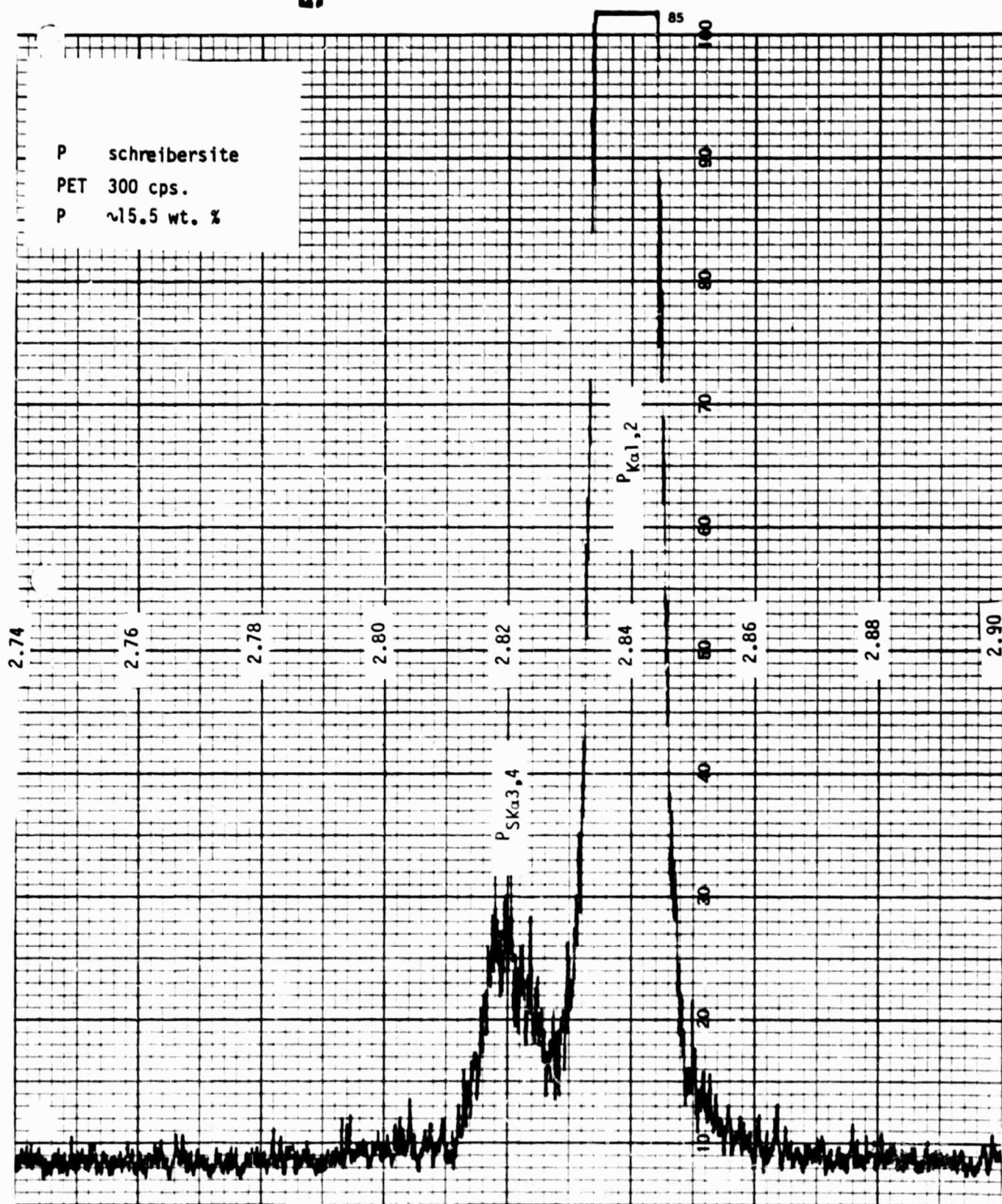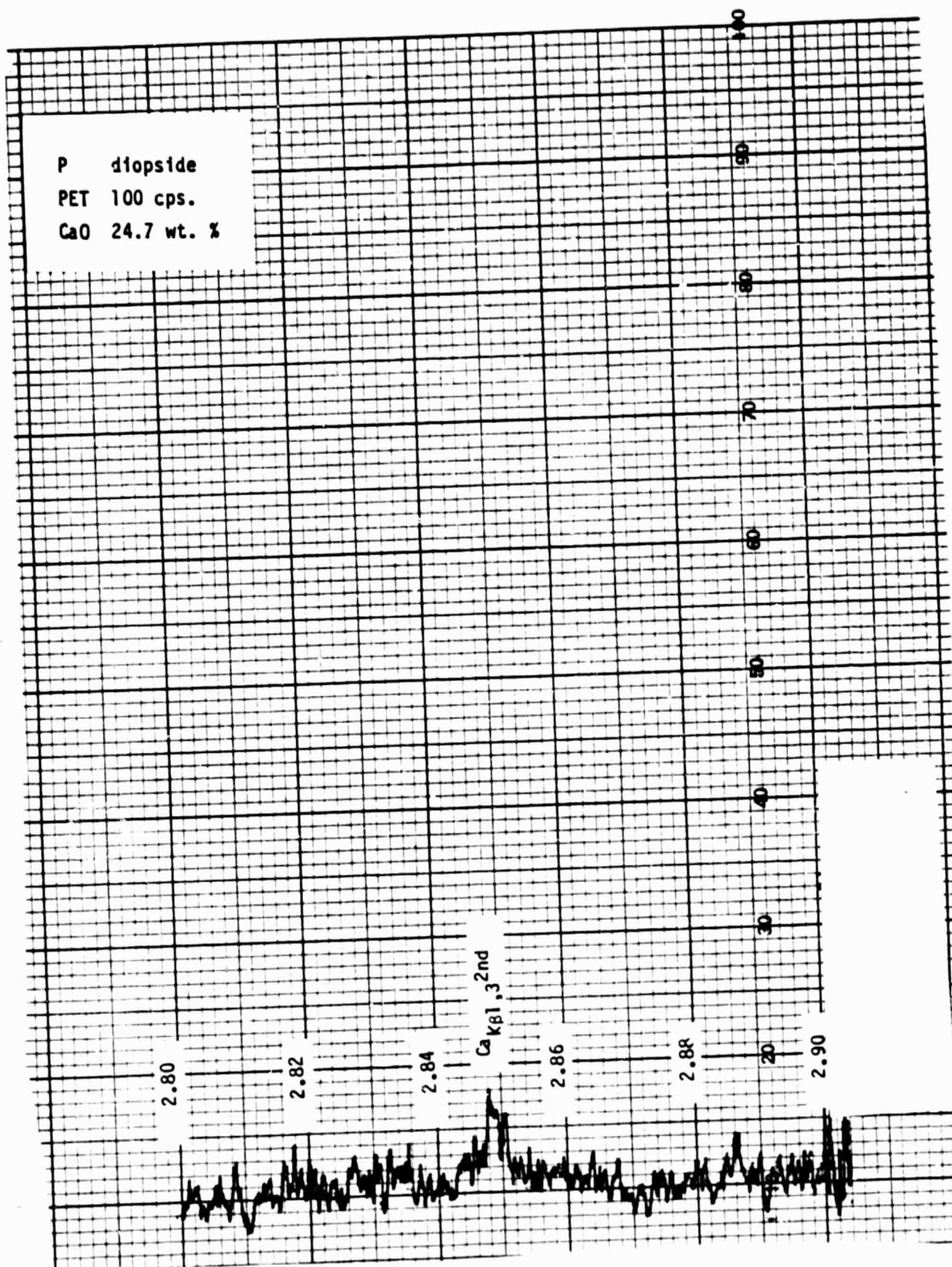
SULFUR

TABLE 16

ELEMENT: S

ANALYTICAL LINE: Kα1,2

CRYSTAL: ADP, PET

SPECTROMETER SETTING: 2.0334(ADP); 2.4749(PET)

BACKGROUND SETTING: ±0.065

ELEMENTAL SCANS:

MINERAL	wt. % S	BACKGROUND SETTING
Troilite	36.47	±0.065
Barite	13.74	±0.040
Co		

INTERFERENCES:

LINE	N	I	ADP (101)	PET (002)	KeV
Fe Kβ5	3	.03	1.9802	2.4102	7.11
Nb Lβ2,15	1	1	1.9822	2.4126	2.37
Hg Lβ1	5	50	1.9843	2.4151	11.82
Tl Mβ	1	55	1.9864	2.4177	2.36
Pt Lα	4	100	1.9876	2.4192	9.44
Sr Kα1,2	6	150	1.9906	2.4227	14.14
Bi Ll	4	3	1.9923	2.4248	9.42
Fe Kβ1,3	3	20	1.9943	2.4273	7.05
Sb Lβ4	2	.1	1.9980	2.4318	4.70
Pb Mα1	1	100	2.0004	2.4348	2.35
As Kβ1	5	15	2.0004	2.4350	11.72
As Kβ3	5	7	2.0016	2.4362	11.72
Pt Lα2	4	10	2.0047	2.4399	9.36
Pb Mα2	1	100	2.0054	2.4407	2.34
W Lβ3	5	2	2.0095	2.4458	11.67
Nb Lβ3	1	3	2.0096	2.4459	2.33
Pt Mδ	1	3	2.0129	2.4500	2.33
Cs Lβ4	2	5	2.0183	2.4565	4.65

S	SKα4	1	45	2.0187	2.4569	2.32
	Au Lβ3	5	6	2.0206	2.4593	11.61
S	SKα3	1	45	2.0212	2.4600	2.32
	Nb Lβ4	1	3	2.0230	2.4622	2.32
	Au Lβ2	5	20	2.0251	2.4647	11.58
S	SKα'	1	.3	2.0259	2.4657	2.32
	Pt M3-N4	1	1	2.0273	2.4675	2.31
	W M2-N4	1	.1	2.0273	2.4675	2.31
	Hg Lβ4	5	4	2.0289	2.4693	11.56
	Nb Lβ6	1	3	2.0289	2.4694	2.31
	Ga Kα1,2	4	150	2.0305	2.4714	9.24
	Cs Lβ1	2	50	2.0312	2.4722	4.62
	Co Kα1,2	3	150	2.0325	2.4738	6.92
S	Kα1,2	1	150	2.0334	2.4749	2.31
	Hg Lδ1	6	10	2.0355	2.4775	13.83
	Zr Lδ?	1	1	2.0376	2.4800	2.30
	Au Lδ3	6	2	2.0386	2.4813	13.81
	Sb Lδ2,3	2	2	2.0400	2.4829	4.60
	Pb L1	4	3	2.0434	2.4871	9.18
	Ir Lα1	4	100	2.0455	2.4896	9.17
	Mo Lα1	1	.00	2.0461	2.4903	2.29
	Mo Lα2	1	10	2.0490	2.4939	2.29
	Au Lβ1	5	50	2.0503	2.4954	11.44
	Te Lδ1	2	9	2.0530	2.4987	4.57
	Hg Mβ	1	50	2.0556	2.5019	2.28
	Ir Lα2	4	10	2.0625	2.5103	9.10
	Tl Mα1	1	100	2.0663	2.5149	2.27
	Tl Mα2	1	100	2.0708	2.5204	2.26
	Nb Lβ1	1	45	2.0785	2.5298	2.26
	W Lδ1	5	10	2.0787	2.5300	11.28

Zr L65	1	.1	2.0805	25323	2.26
Ti kα1,2	2	150	2.0812	2.5331	4.51
Ir M6	1	1	2.0814	2.5333	2.25
Pt Lβ2	5	20	2.0852	2.5379	11.25
Pt Lβ3	5	6	2.0882	2.5416	11.23
Se kα1,2	5	150	2.0930	2.5474	11.21
Au Lβ4	5	4	2.0937	2.5483	11.20
Bi M3-N1	1	1	2.0954	2.5504	2.24
Tl L1	4	3	2.0962	2.5513	8.95
Ir M3-N4	1	.1	2.0966	2.5517	2.24
Ba Lα1	2	100	2.1011	2.5572	4.47

NOTES: Sulfur appears to be a difficult element to analyze for depending on the mineral matrix. Of particular importance are $Pb_{M\alpha1}$, $Pb_{M\alpha2}$, $Ga_{K\alpha1,2}$, $Cs_{L\beta1}$, $Co_{K\alpha1,2}$, Ir_{L1}, $Mo_{L\alpha1}$ and $Tl_{M\alpha1}$. Of these, Pb, Mo and Tl are first order X-ray lines of almost identical energy as $S_{K\alpha1,2}$ (2.31 KeV) and therefore not separable from sulfur with a PHA. Other interfering lines can be discriminated against with a PHA.

S troilite
ADP 300 cps.
S 36.47 wt. %

$S_{K\alpha1,2}$

$S_{K\alpha3,4}$

$Fe_{K\beta1,3}$rd

1.94 1.96 1.98 2.00 2.02 2.04 2.06 2.08 2.10 2.12

100 90 80 70 60 50 40 30 20 10

S   barite
ADP 300 cps.
S   13.72 wt. %

1.92

1.94

$Ba_{L\beta1}$ 2nd

1.96

1.98

2.00

2.02

$S_{SK\alpha3,4}$

$S_{K\alpha1,2}$

2.04

2.06

2.08

2.10

$Ba_{L\alpha1}$ 2nd

2.12

2.14

2.16

S   Co 99.9
ADP 300 cps.

Co$_{K\alpha1,2}$3rd

1.98   2.00   2.02   2.04   2.06   2.08   2.10   2.12
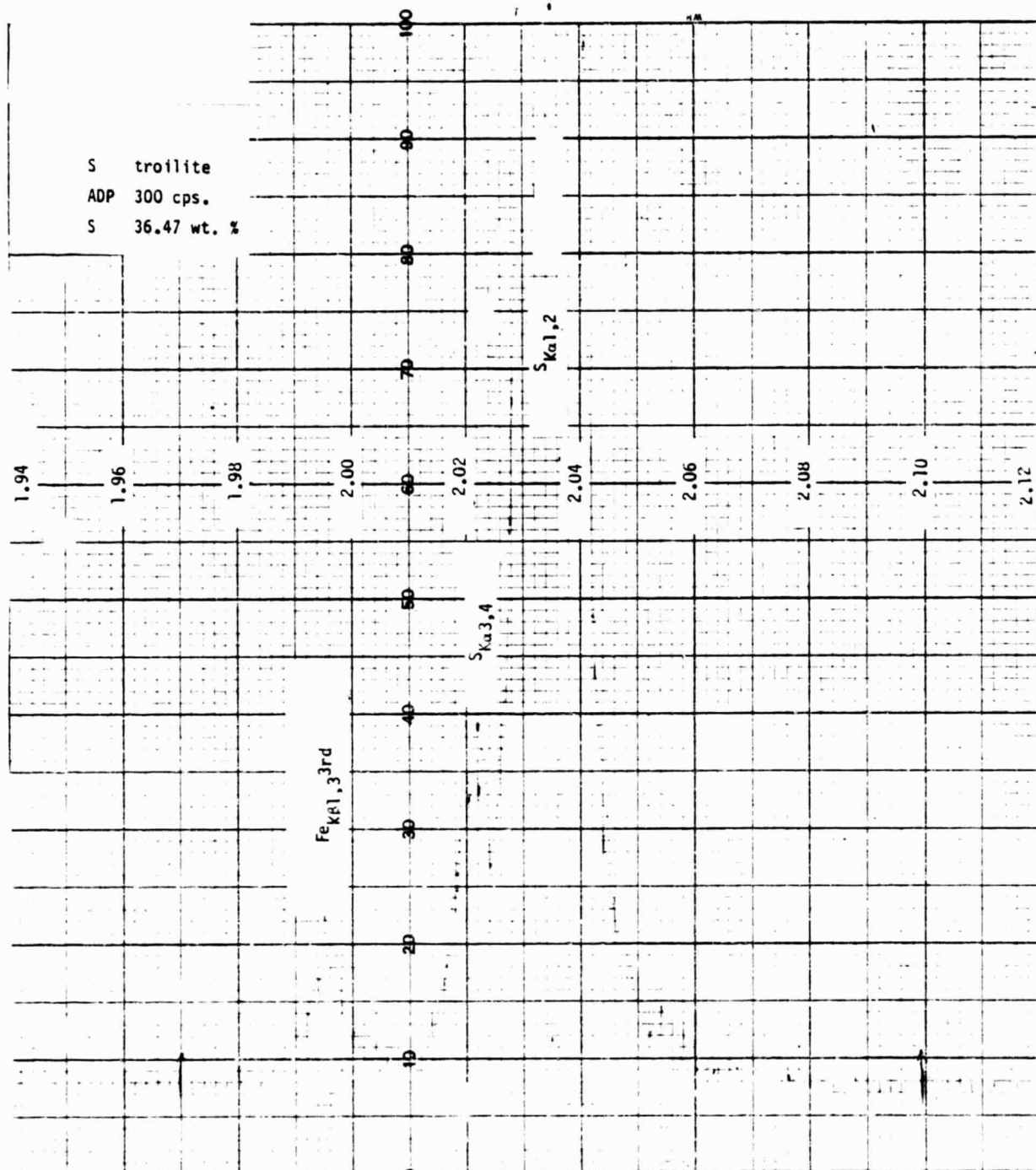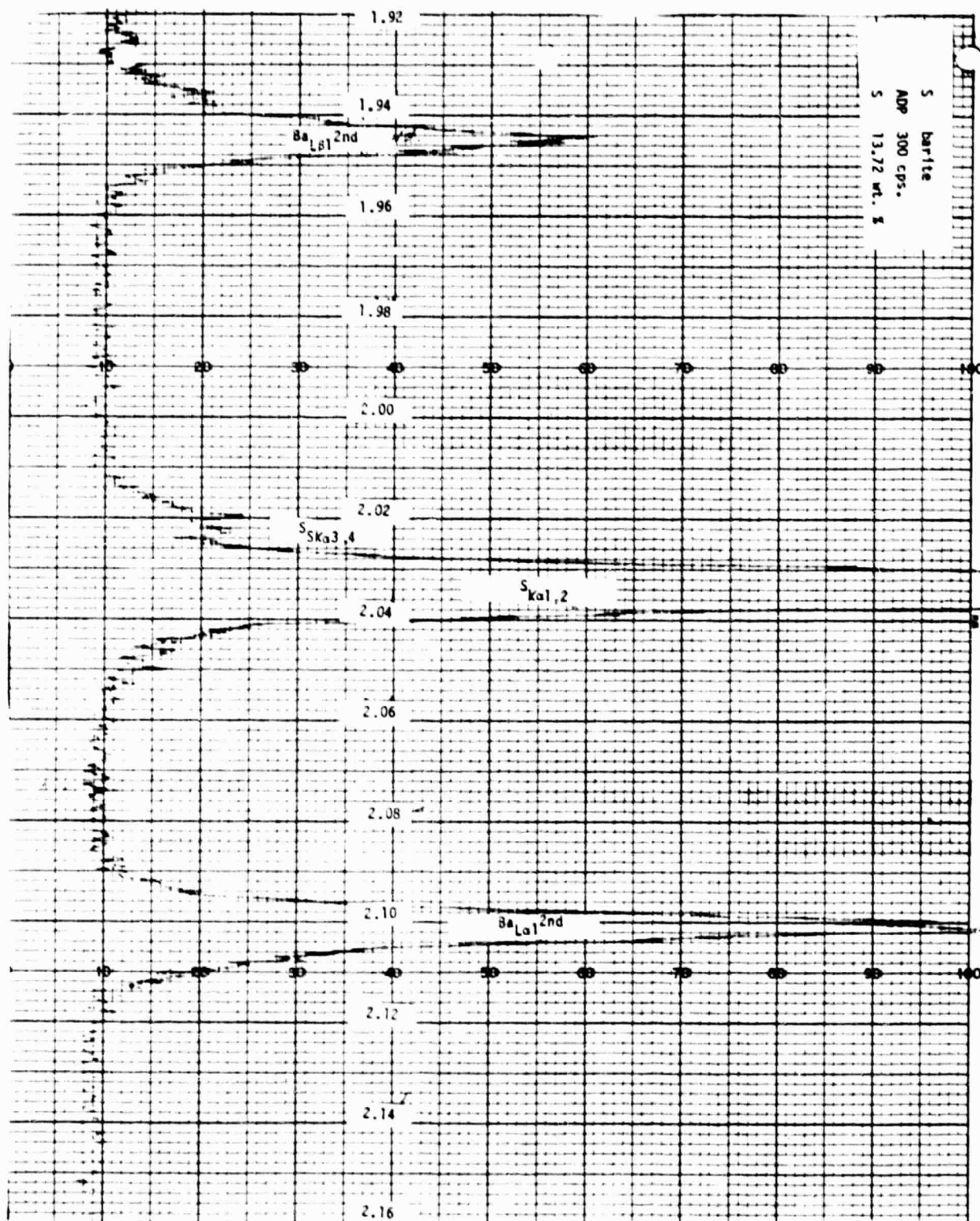
S   troilite
PET   300 cps.
S   36.47 wt. %

CHLORINE

TABLE 17

ELEMENT: Cℓ

ANALYTICAL LINE: Kα1,2

CRYSTAL: PET

SPECTROMETER SETTING: PET 2.1781

BACKGROUND SETTING: ±0.030

ELEMENTAL SCANS:

MINERAL	WT. % Cℓ	BACKGROUND SETTING
Scapolite	2.19	±0.030

INTERFERENCES:

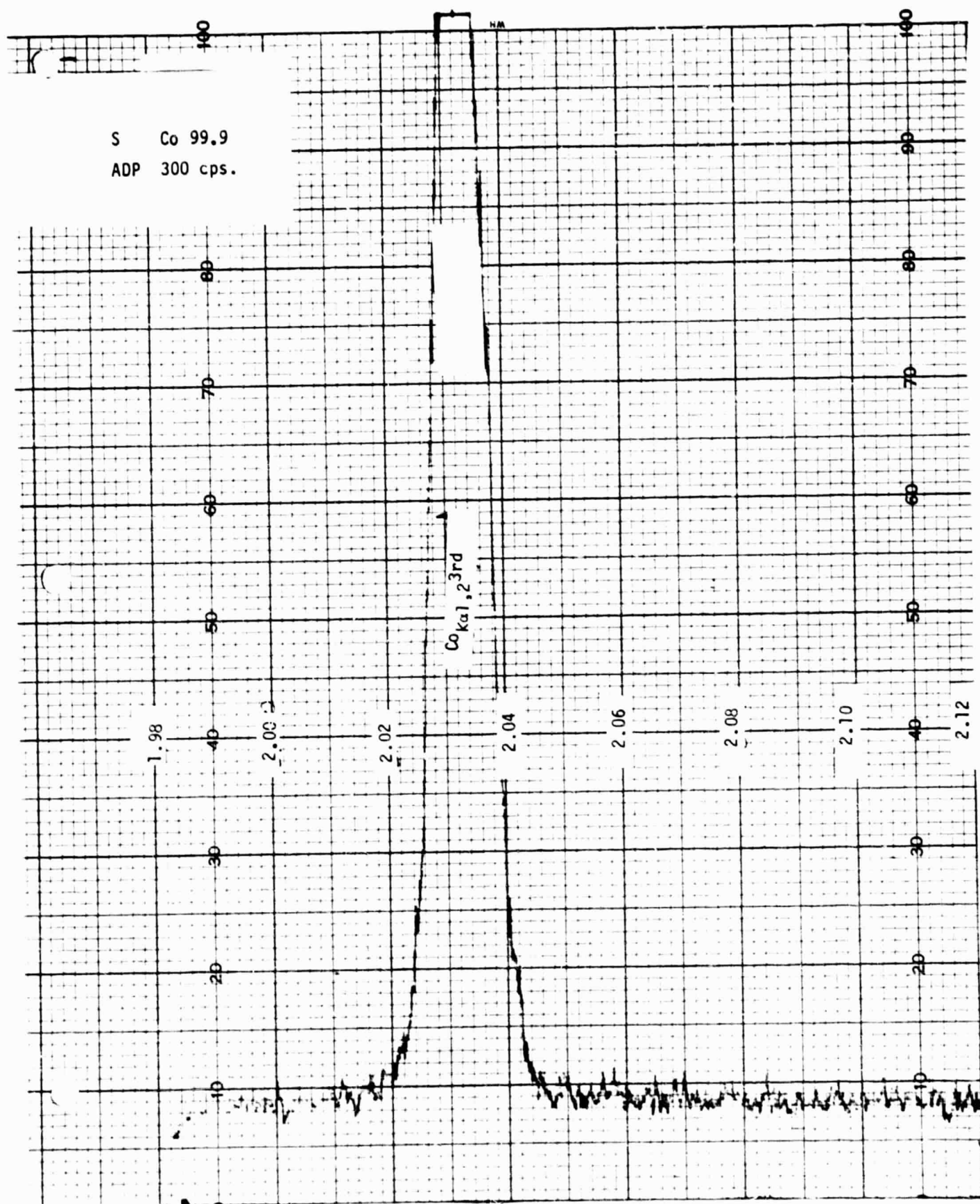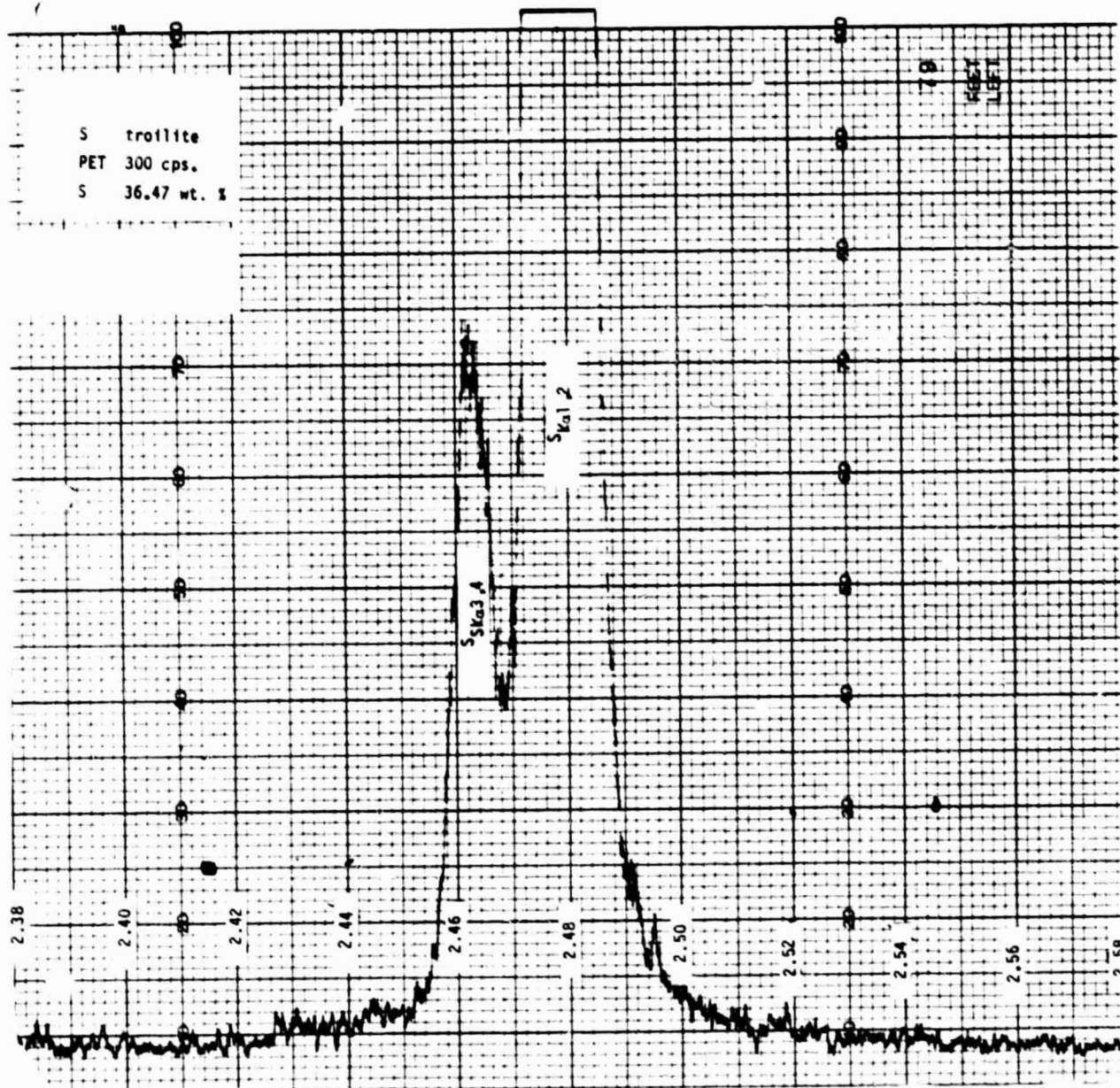|	LINE	N	I	ADP (101)	PET (002)	KeV
	Ho Lβ10	3	.01	1.7582	2.1399	8.00
	Nb Lδ2,3	1	.5	1.7613	2.1437	2.66
	Er Lβ3	3	6	1.7729	2.1578	7.94
	Gd Lδ6	3	.01	1.7761	2.1617	7.92
Cℓ	SKα4	1	4	1.7770	2.1628	2.64
	Sr Kβ1	6	16	1.7777	2.1637	15.83
	Ce Lβ4	2	5	1.7784	2.1646	5.28
	Sr Kβ3	6	8	1.7789	2.1652	15.82
	Ho Lβ2,15	3	20	1.7792	2.1654	7.91
	Er Lβ6	3	.1	1.7796	2.1660	7.91
	As Kα1,2	4	150	1.7820	2.1689	10.53
Cℓ	SKα3	1	4	1.7828	2.1699	2.63
	Gd Lδ8	3	.1	1.7832	2.1704	7.89
	Ce Lβ1	2	50	1.7833	2.1705	5.26
Cℓ	Kα1,2	1	150	1.7896	2.1781	2.62
	Tb Lδ5	3	.1	1.7923	2.1815	7.85
	Nd Lα1	2	100	1.7941	2.1836	5.23
	Th Lβ4	6	4	1.7996	2.1904	15.64
	La Lβ6	2	.1	1.8006	2.1916	5.21
	Th Lβ2	6	20	1.8018	2.1930	15.62
	Nd Lα2	2	10	1.8019	2.1931	5.21

Er Lβ1	3	50	1.8021	2.1933	7.81
Dy Lβ5	3	.1	1.8033	2.1948	7.80
Yb L2-M2	3	.01	1.8034	2.1949	7.80
Eu Lδ3	3	1	1.8055	2.1975	7.80
Gd Lδ1	3	5	1.8079	2.2004	7.78
Th Lα1	5	100	1.8089	2.2017	12.97

NOTES: Cℓ is commonly found in sodalite, apatite and scapolite associated with REE, Sr, Th, As, V and F. Of these elements the REE could create most of the interference problems but they commonly occur in sufficiently low concentrations so as not to interfere with the Cℓ determination. All but the Nb Lδ2,3 line could be discriminated against with a PHA window.

Cℓ scapolite
PET 300 cps.
Cℓ   2.19 wt. %

POTASSIUM

K   orthoclase
PET   300 cps.
K₂0   15.36 wt. %

$K_{K\beta 1,3}$

$K_{K\alpha 1,2}$

1.54
1.56
1.58
1.60
1.62
1.64
1.66
1.68
*(030)
1.70
1.72
1.74
*(030)
1.76
1.78
1.80
1.82
1.84
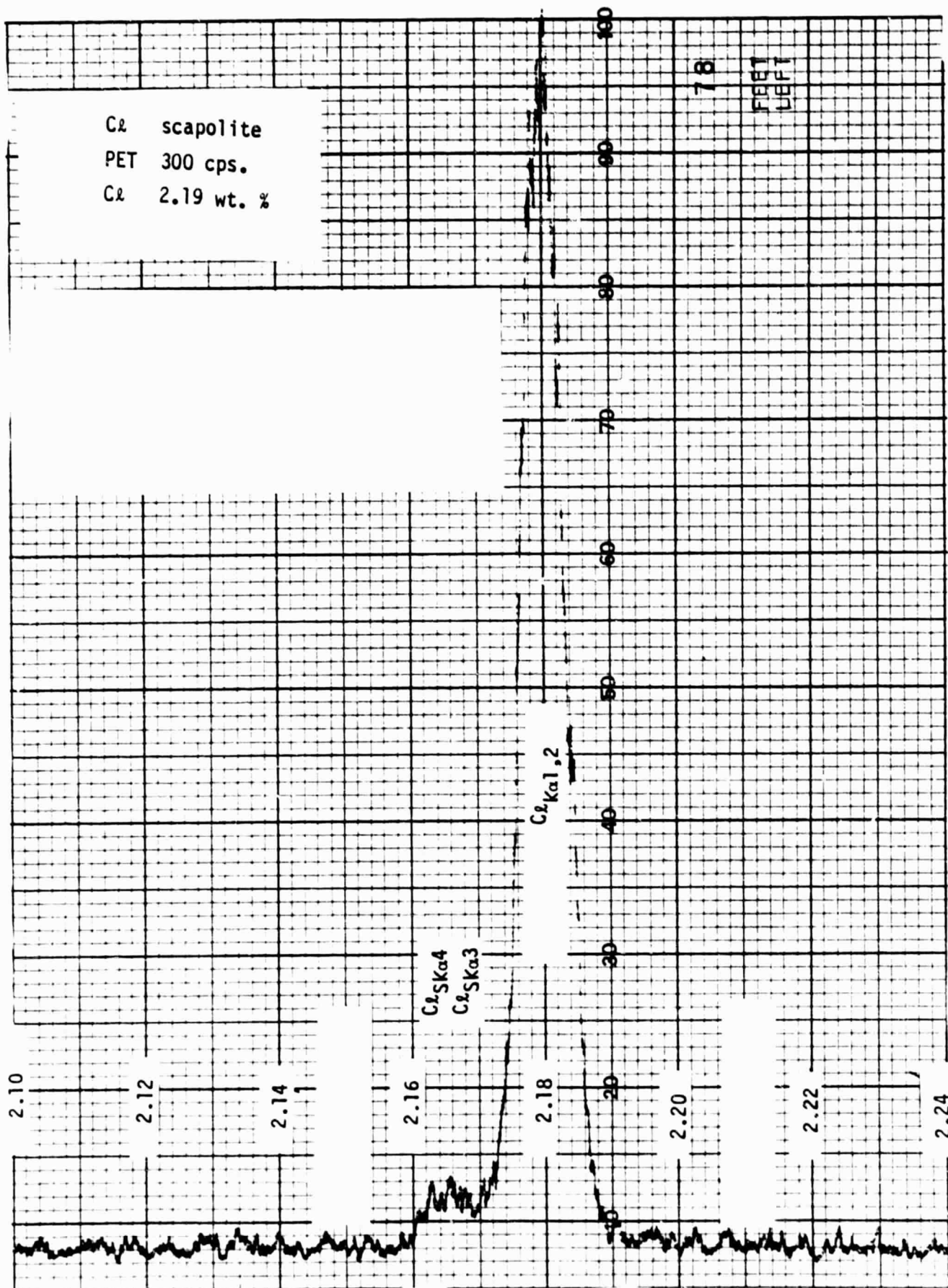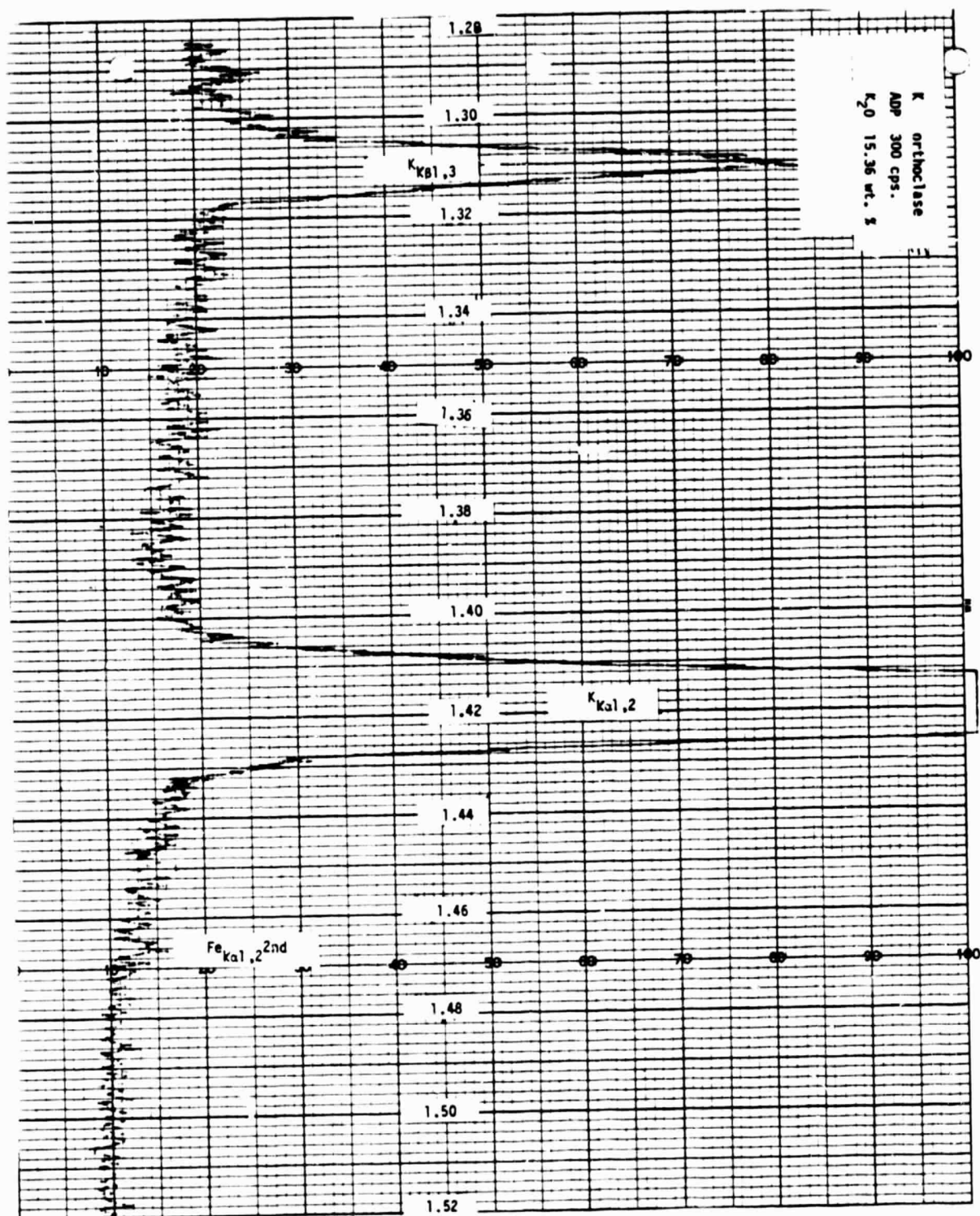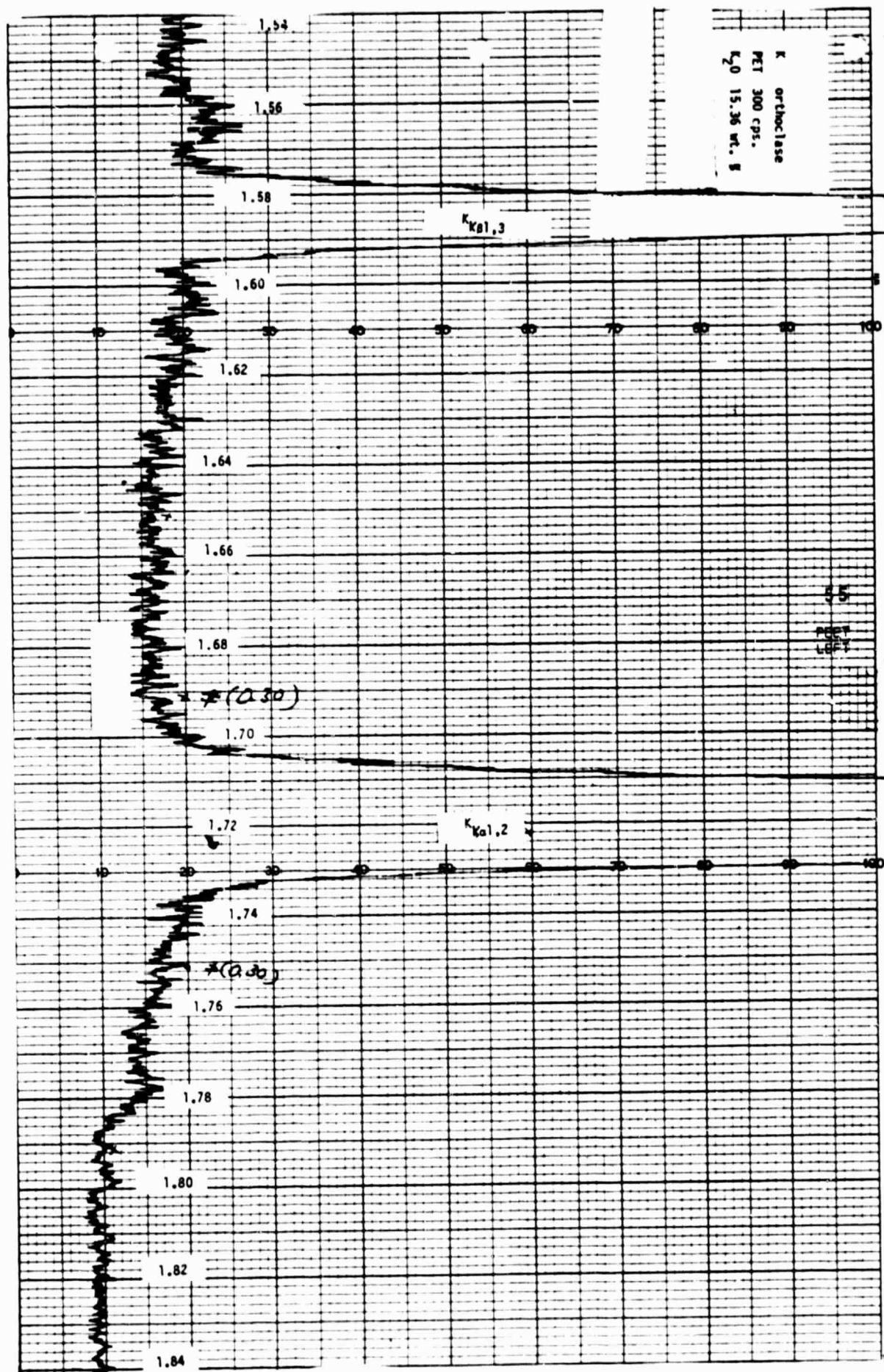
K   kaersutite
ADP 300 cps.
K_2O 1.59 wt. %

85

K   kaersutite
PET 300 cps.
K_2O 1.59 wt. %

$K_{K\alpha1,2}$

$F_{K\alpha1,2}$ 2nd

1.66 1.68 1.70 1.72 1.74 1.76 1.78 1.80 1.82
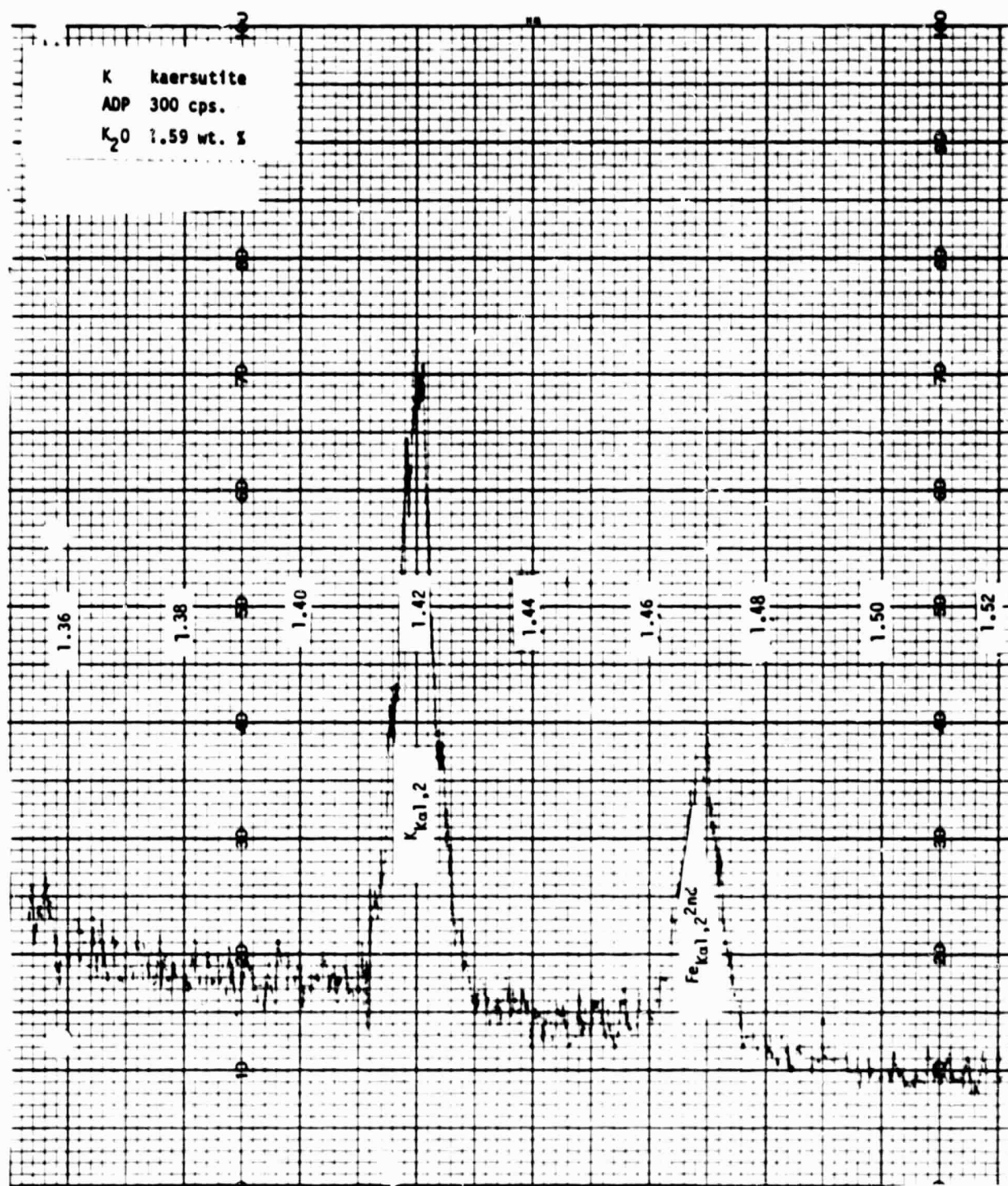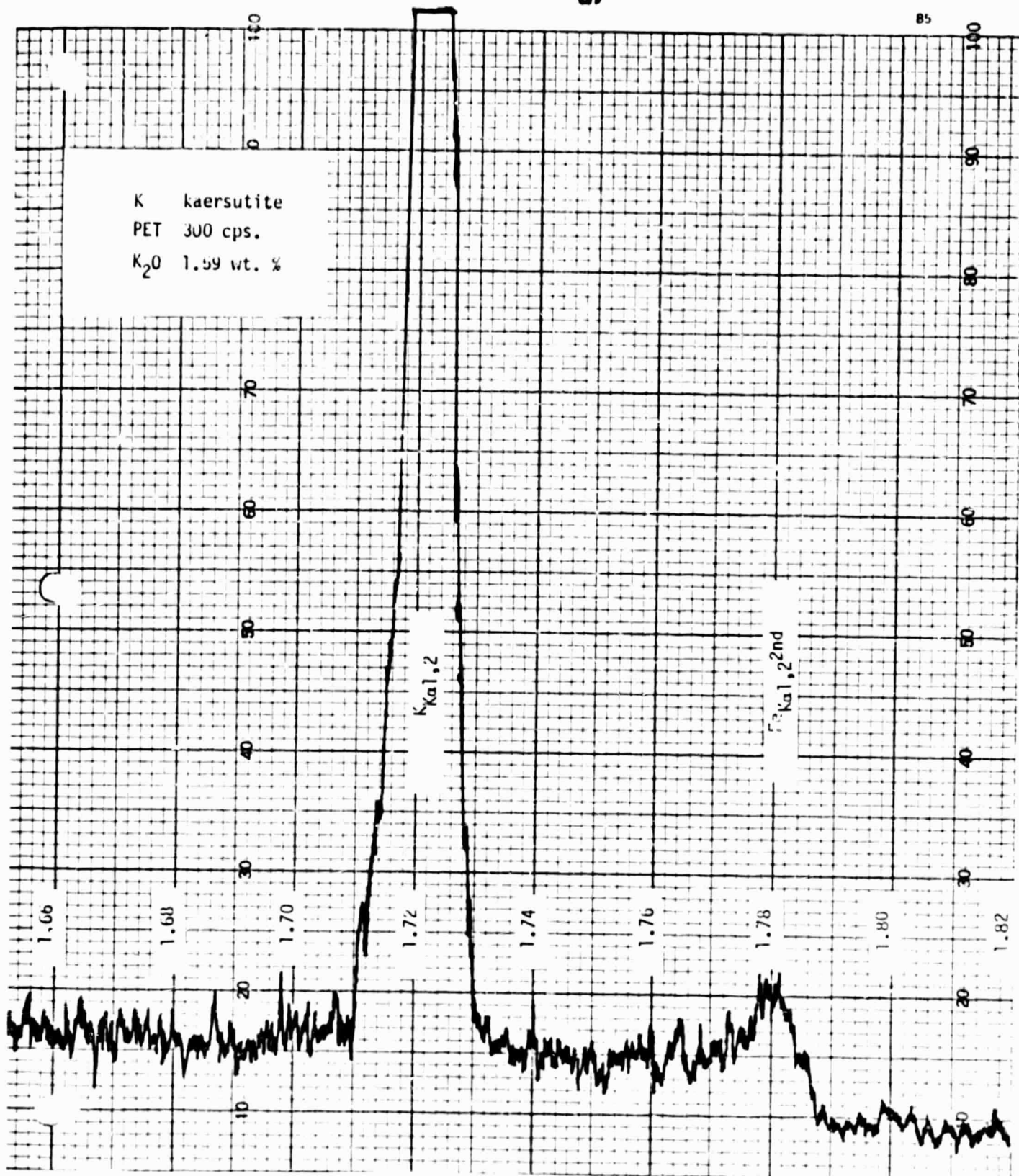
CALCIUM

TABLE 20

ELEMENT: Ca

ANALYTICAL LINE: Kα1,2

SPECTROMETER SETTING: 1.2714(ADP); 3.3595(LiF); 1.5474(PET)

BACKGROUND SETTING: ±0.046(ADP); ±0.052(LiF); ±0.034(PET)

ELEMENTAL SCANS:

MINERAL	WT.% OXIDE	BACKGROUND SETTING
CPX CP19	18.13	±0.046 ADP
		±0.052 LiF
		±0.034 PET
Kaersutite	10.12	±0.034 PET

INTERFERENCES:

	Line	N	I	ADP (101)	LiF (200)	PET (002)	KeV
	Sm Lδ3	2	1	1.2534	3.3120	1.5255	7.49
	Eu Lδ1	2	5	1.2545	3.3148	1.5268	7.48
	Tb Lβ7	2	.1	1.2553	3.3170	1.5278	7.47
	Ni Kα1,2	2	150	1.2558	3.3184	1.5285	7.47
	Ho Lβ4	2	5	1.2560	3.3190	1.5287	7.47
	Sm Lδ2	2	1	1.2568	3.3209	1.5296	7.47
	Y Kα1,2	4	150	1.2568	3.3210	1.5297	14.93
	Nb Kβ3	5	7	1.2608	3.3317	1.5346	18.6J
	Tb Lβ10	2	.01	1.2619	3.3346	1.5359	7.44
Ca	SKα4	1	2	1.2628	3.3369	1.5370	3.72
Ca	SKα3	1	2	1.2640	3.3401	1.5385	3.71
	Po Lα1	3	100	1.2646	3.3416	1.5391	11.13
	Yb Lα1	2	100	1.2654	3.3438	1.5402	7.41
Ca	Kα1,2	1	150	1.2714	3.3595	1.5474	3.69
	Dy Lβ6	2	.1	1.2732	3.3643	1.5496	7.37
	Dy Lβ3	2	6	1.2732	3.3644	1.5497	7.37
	Yb Lα2	2	10	1.2737	3.3657	1.5503	7.37
	Tb Lβ2,15	2	20	1.2738	3.3650	1.5504	7.37

Po Lα2	3	10	1.2778	3.3764	1.5552	11.01
Sm Lδ8	2	.1	1.2915	3.4127	1.5719	7.27
Eu Lδ5	2	.1	1.2931	3.4170	1.5739	7.26

NOTES: No interference problems typically exist due to the low concentrations
        of REE in most silicates. A high Ni concentration   might present
        some problem but a PHA should be helpful in that case. If K is
        present and the analyzing crystal is PET, careful background selection
        is required. (See kaersutite scan.)

Ca   Clinopyroxene CP19
ADP   300 cps.
CaO   18.13 wt. %

$Ca_{k\alpha1,2}$
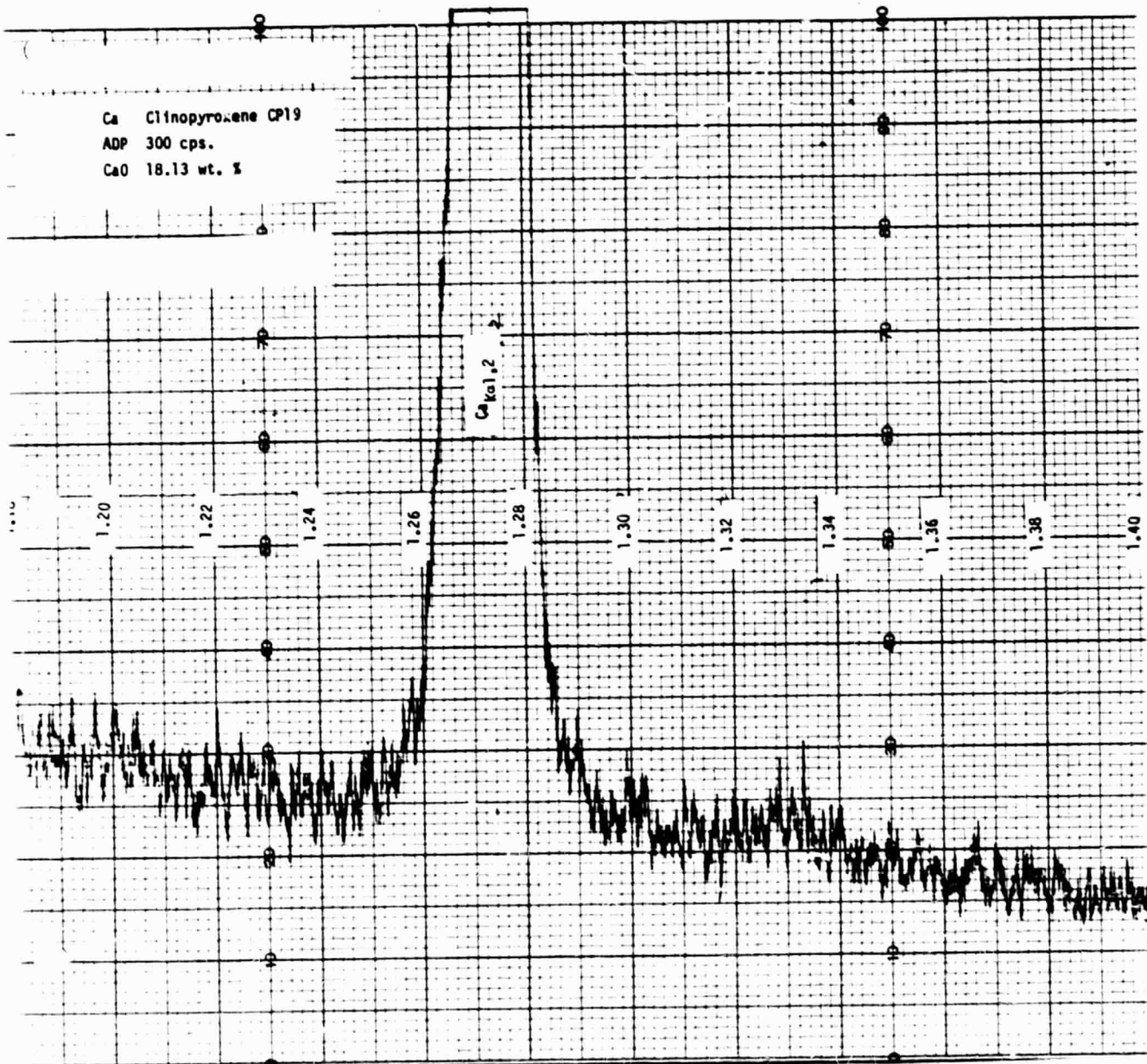
Ca   Clinopyroxene CP19
LiF   300 cps.
CaO   18.13 wt. %

Ca$_{K\alpha1,2}$

Ca$_{SK\alpha4}$
Ca$_{SK\alpha3}$

3.26 3.28 3.30 3.32 3.34 3.36 3.38 3.40 3.42 3.44

53

FEET LEFT

Ca   Clinopyroxene CP19
PET   300 cps.
CaO   18.13 wt. %

$Ca_{K\beta 1,3}$

$Ca_{K\alpha 1,2}$

1.38

1.40

1.42

1.44

1.46

1.48

1.50

1.52

1.54

1.56

1.58

1.60

1.62

1.64

Ca$_{K\alpha1,3}$

Ca$_{K\alpha1,2}$

K$_{K\alpha1,3}$

52

FEET
LEFT
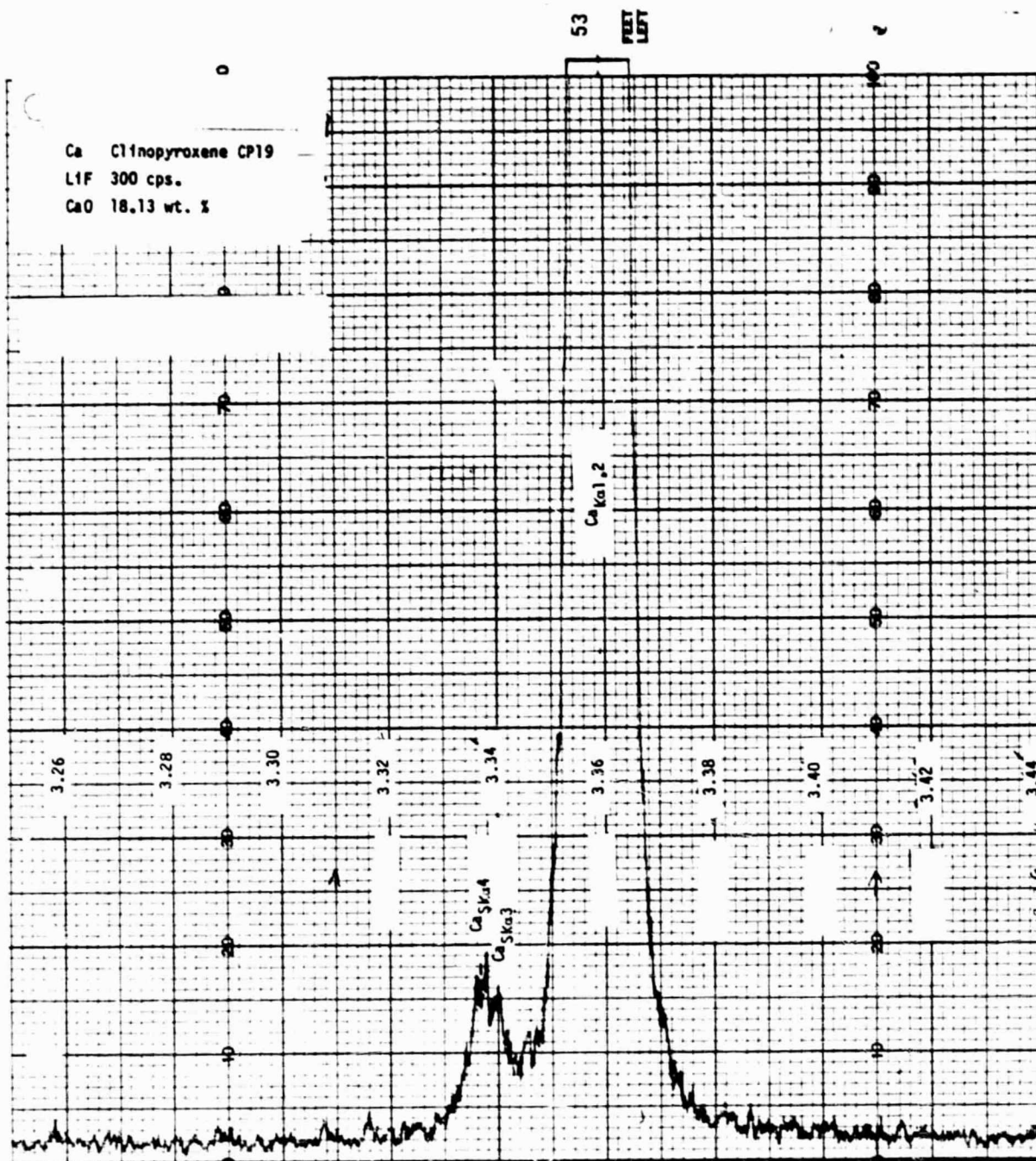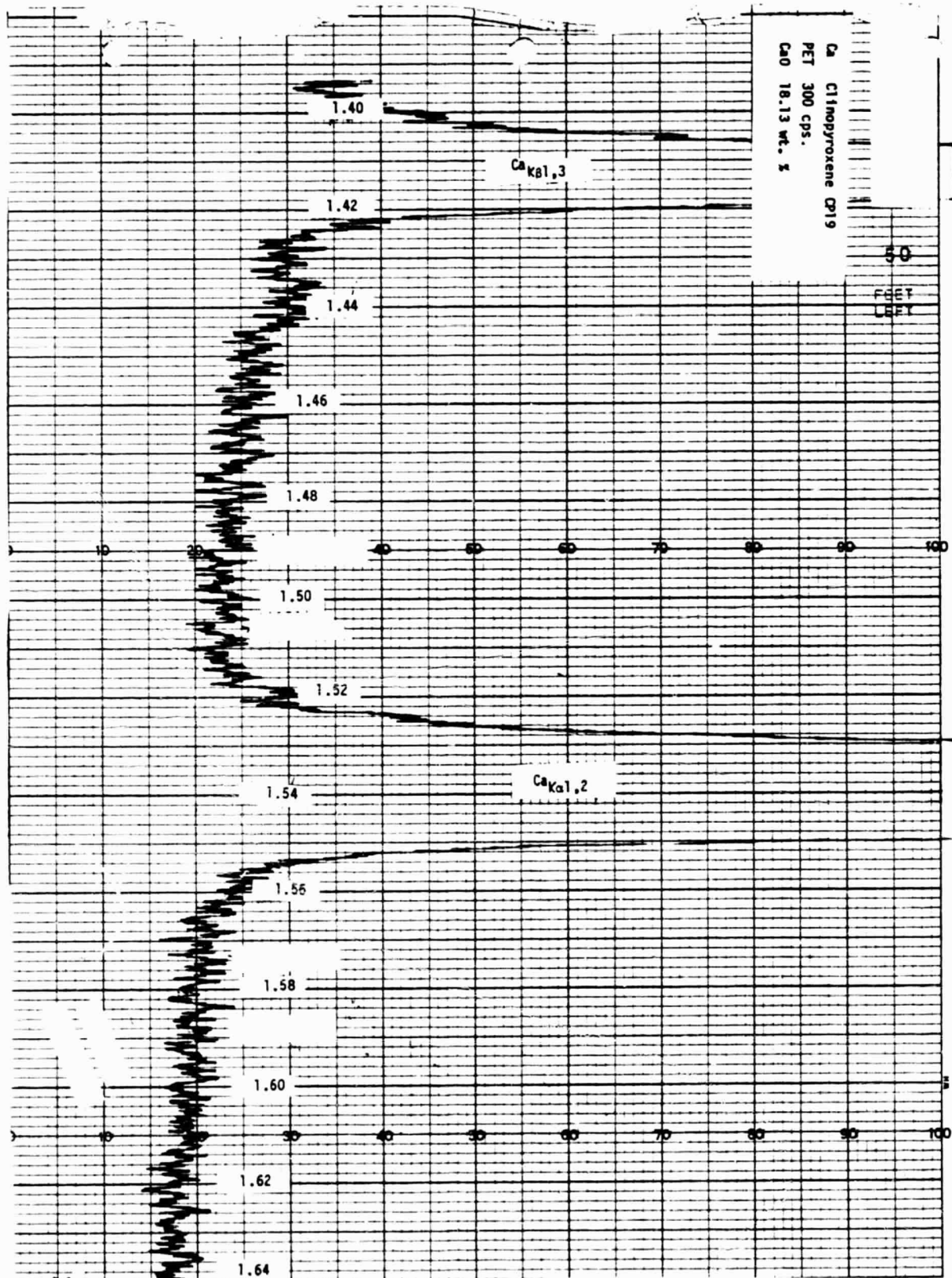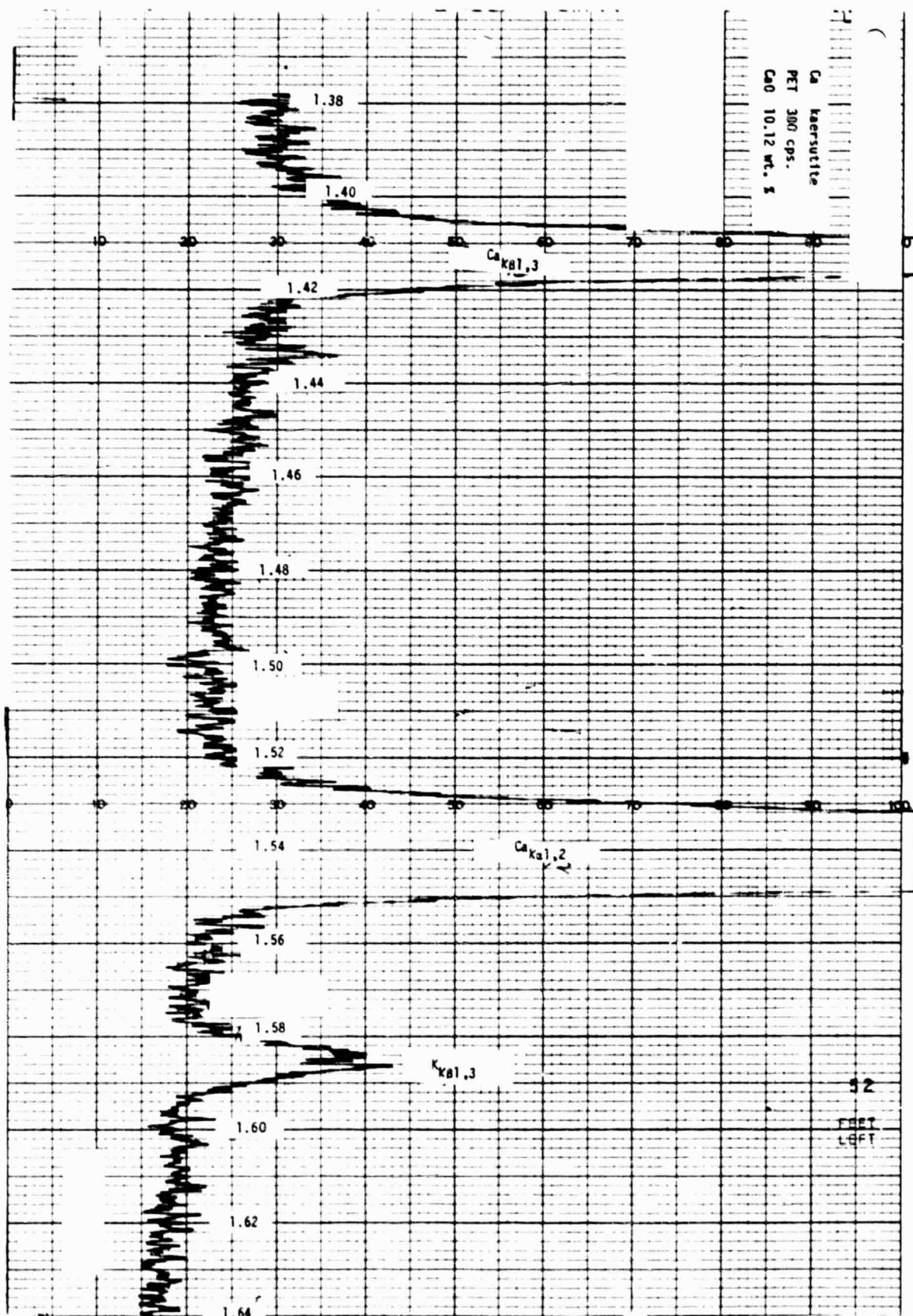
TITANIUM

TABLE 22

ELEMENT: Ti

ANALYTICAL LINE: Kα1,2

CRYSTAL: LiF, PET

SPECTROMETER SETTING: 2.7497, 1.2665

BACKGROUND SETTING: ±0.058

ELEMENTAL SCANS:

MINERAL	WT. % OXIDE	BACKGROUND SETTING
rutile	100.00	±0.080
ilmenite	50.04	±0.058
kaersutite	5.64	±0.058
Ti metal (99.9)		

INTERFERENCES:

	LINE	N	I	LiF (200)	PET (002)	KeV
	Cs Lβ4	1	5	2.6730	1.2312	9.28
	La Lα2	1	10	2.6753	1.2323	4.63
	Nd L1	1	2	2.6760	1.2326	4.63
	Cs Lβ1	1	50	2.6837	1.2361	4.62
	U Lα1	3	100	2.7319	1.2583	13.61
	La Ln	1	1	2.7400	1.2621	4.52
	Lu Lβ15	2	20	2.7430	1.2634	9.04
	Hf Lβ1	2	50	2.7482	1.2658	9.02
Ti	Kα1,2	1	150	2.7497	1.2665	4.51
	Po Lβ1	3	50	2.7650	1.2740	13.44
	Ba Lα1	1	100	2.7760	1.2786	4.47
	Sc Kβ1,3	1	20	2.7796	1.2803	4.46
	Rb Kα1,2	3	150	2.7808	1.2808	13.37
	Pr L1	1	2	2.7841	1.2824	4.45
	Cu Kβ1,3	2	20	2.7844	1.2825	8.90
	Cu Kβ3	2	6	2.7852	1.2829	8.90
	Ba Lα2	1	10	2.7855	1.2830	4.45
	Zr Kβ1	4	18	2.8069	1.2929	17.67
	U M2-N4	1	5	2.8170	1.2975	4.40

NOTES: Commonly no interferences occur with a Ti determination with the exception of a high Ba matrix, i.e., benitoite. Other interferences will probably not be encountered. Ba interference cannot be separated with a PHA.

08

FILE LEFT

T1   TiO$_2$
LiF   300 cps.
TiO$_2$ 100.0 WT. %

? NOT LISTED

T1 Kα1.2

2.66   2.68   2.70   2.72   2.74   2.76   2.78   2.80   2.82   2.84
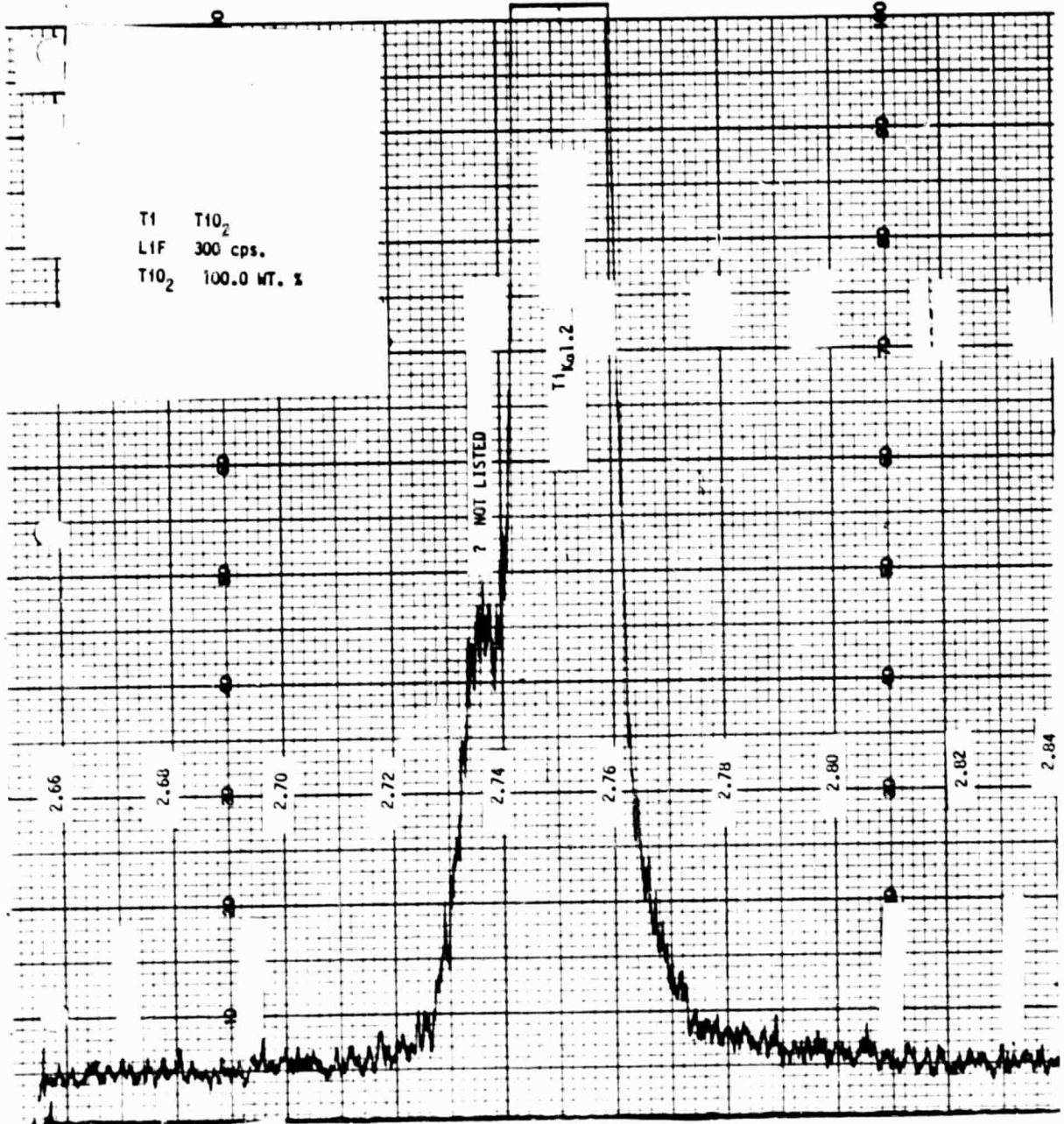
Ti   ilmenite, Elliot Co.
LiF   300 cps.
TiO_2 50.04 WT. %

$Ti_{K\alpha 1,2}$

? NOT LISTED

2.67   2.69   2.71   2.73   2.75   2.77   2.79   2.81   2.83
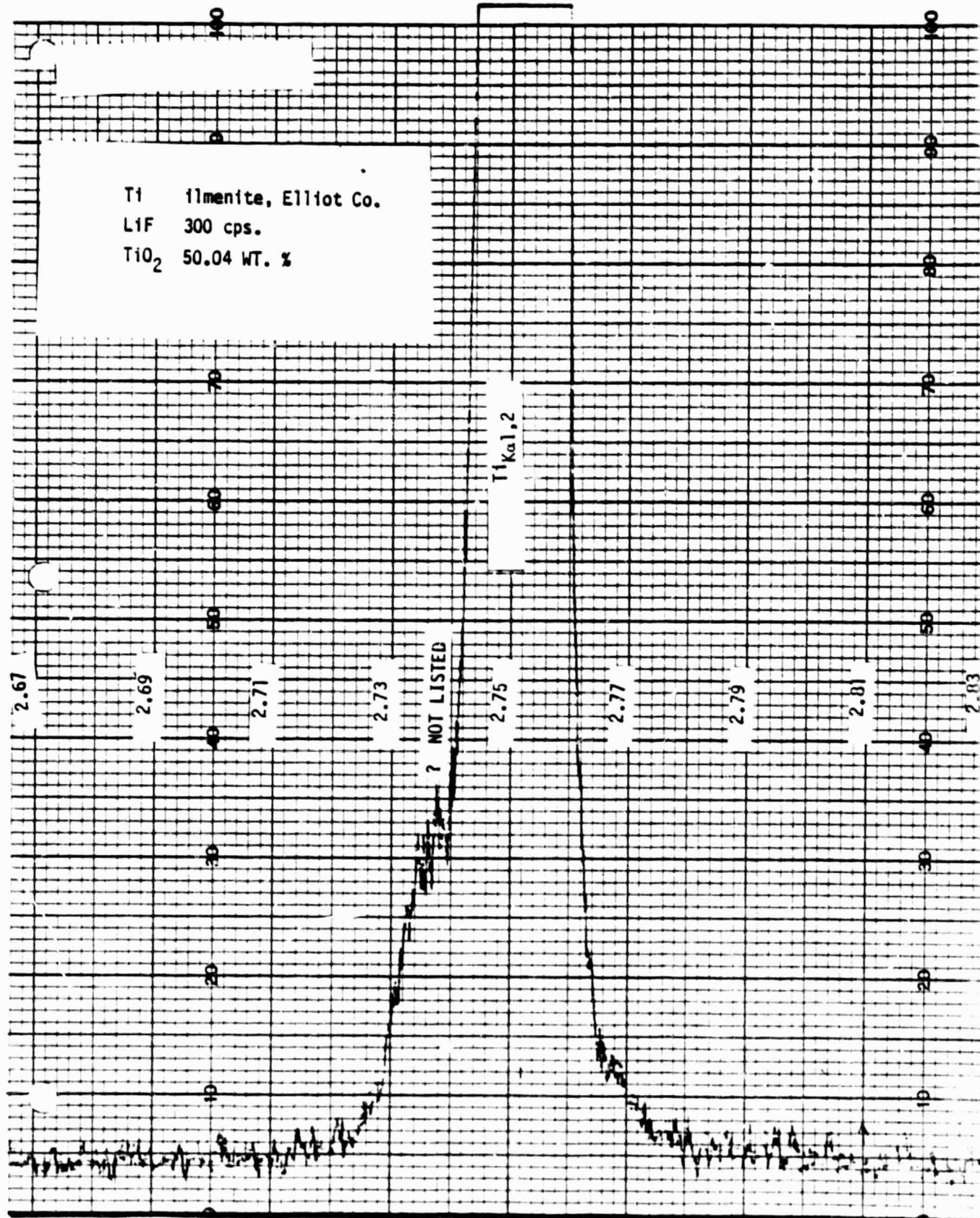
Ti   Kaersutite, Spring Mtn.
LiF   300 cps.
TiO_2 5.64 wt. %

$Ti_{K\alpha 1,2}$

2.69
2.71
2.73
2.75
2.77
2.79
2.81
2.83

32

FEET LEFT

Ti   Ti metal
PET   1000 cps

1000cps

? NOT LISTED

Ti Kα$_{1,2}$

1.220
1.240
1.260
1.280
1.300
1.320
1.340
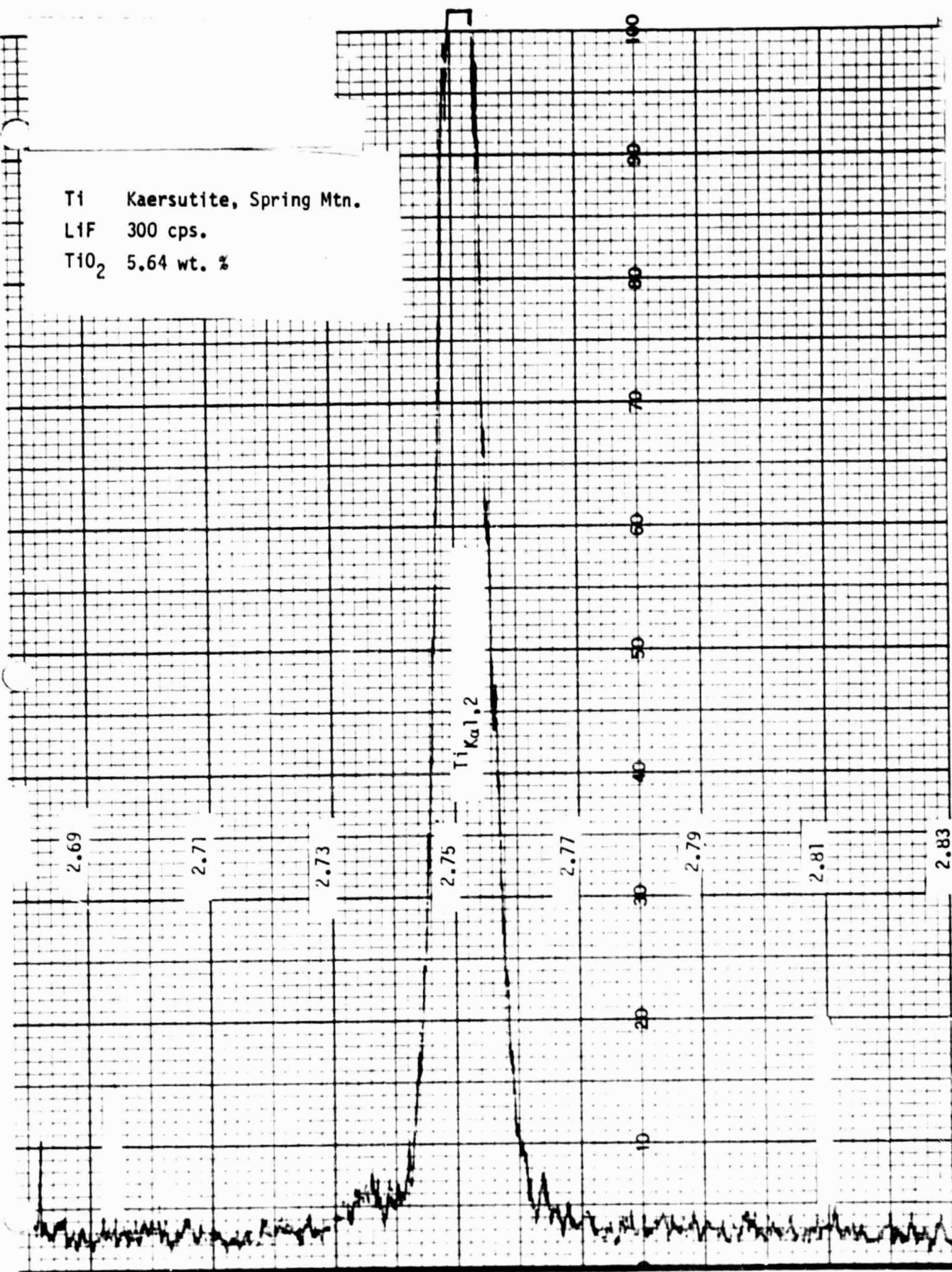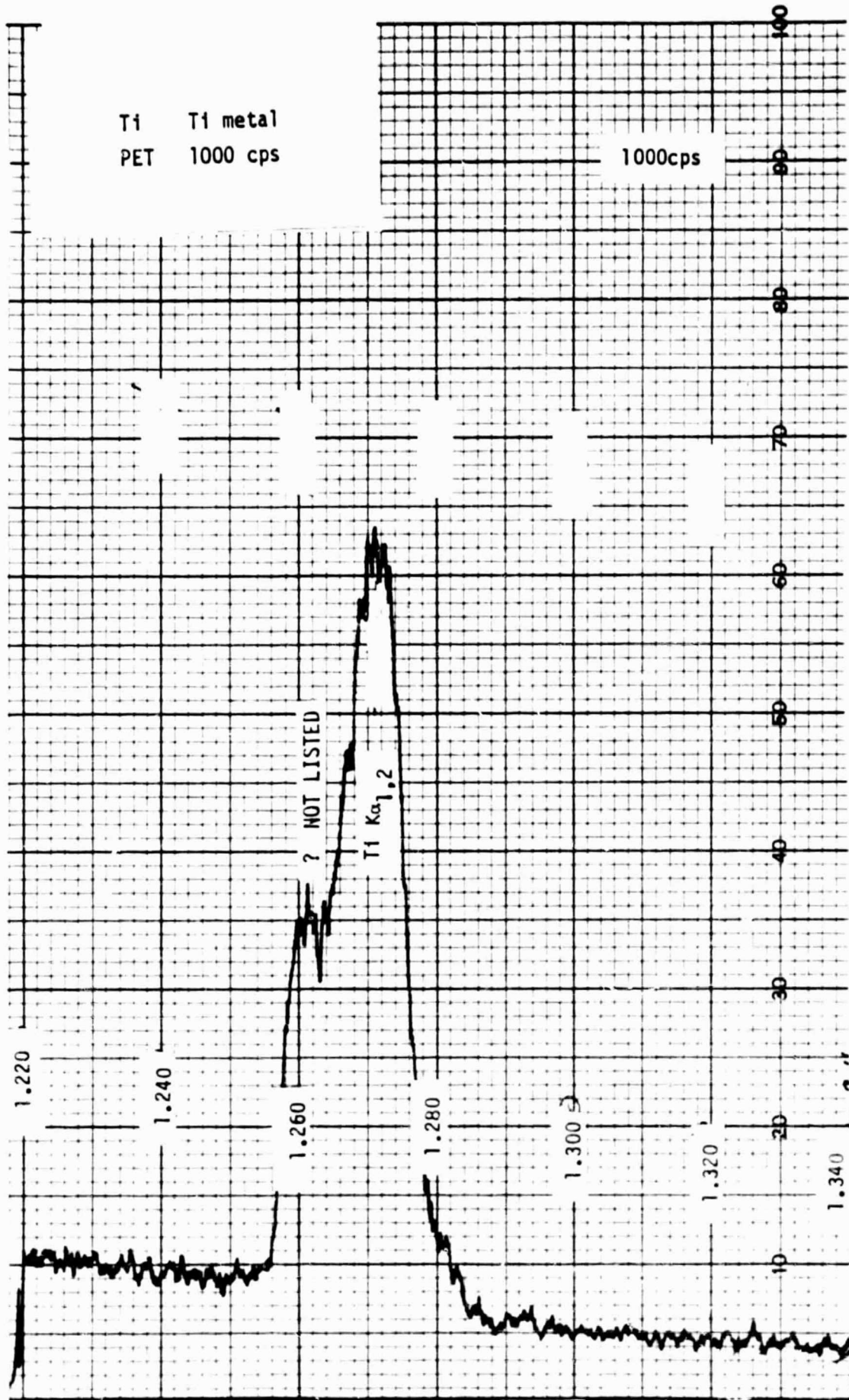
VANADIUM

TABLE 23

ELEMENT: V

ANALYTICAL LINE: Kα1,2

CRYSTAL: LiF

SPECTROMETER SETTING: 2.5048

BACKGROUND SETTING: ±0.057, ±0.029

ELEMENTAL SCANS:

MINERAL	WT. %	BACKGROUND SETTING
V_2O_5	99.99	±0.057
magnetite	?	±0.029
ilmenite	?	-0.029
V, Ti overlay		

INTERFERENCES:

LINE	N	I	LiF (200)	KeV
La Lβ4	1	5	2.4493	5.06
La Lβ1	1	50	2.4589	5.04
Pr Lα1	1	100	2.4630	5.03
Sm L1	1	2	2.4823	4.99
Ba Lβ6	1	.1	2.4826	4.99
Y Kα1,2	3	150	2.4907	14.93
Ti Kβ5	1	.02	2.4985	4.96
V Kα1,2	1	150	2.5048	4.95
Ge	2	150	2.5107	9.87
Pr LN	1	1	2.5120	4.94
Ti Kβ1,3	1	20	2.5139	4.93
Ba Lβ3	1	6	2.5164	4.93
Ba Lβ4	1	5	2.5553	4.85
Ce Lα1	1	100	2.5615	4.84

NOTES: The most likely problem to occur is the Ti Kβ1.3 interference on VKα1,2. A PHA cannot be used as a discriminator due to the similar energies of the two lines. Using a V free sample, i.e. TiO_2, ilmenite, etc. determine the intensity contribution at the V peak position and subtract off the appropriate amount from the V counts. See Geissman and Essene, "A graphic method of resolving X-ray interference on the electron microprobe", 13th Proceedings of the Microbeam Analysis Society. Ge interference can be discriminated against using a PHA.
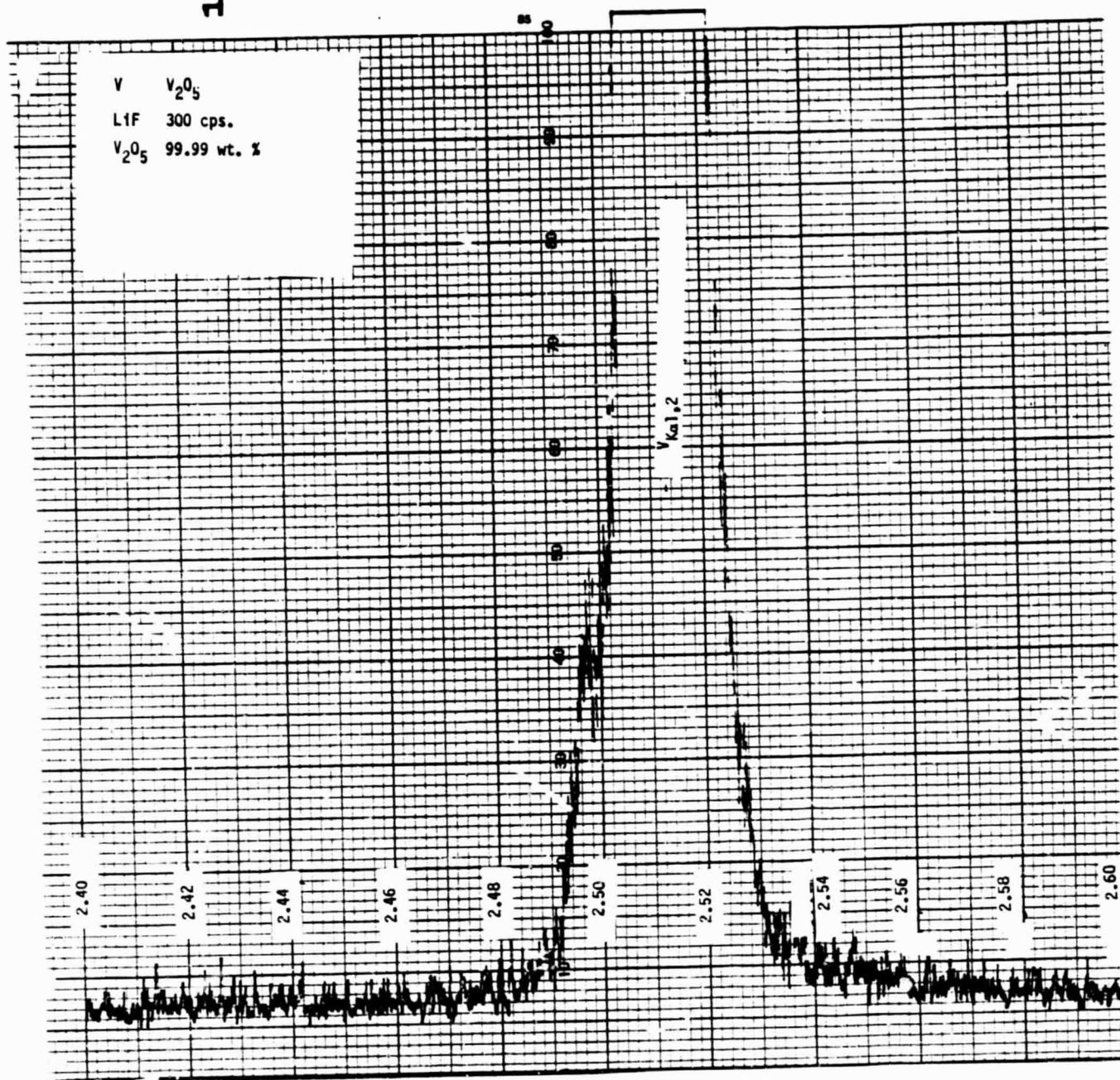
V   magnetite, section 3A

LiF 300 cps.

V_2O_3 ? wt. %

14

V   ilmenite, Elliot Co.
LiF   300 cps.
V_2O_5 ?

Ti$_{K\beta 1,3}$

Ti$_{K\beta 5}$

V$_{K\alpha 1,2}$

2.40 2.42 2.44 2.46 2.48 2.50 2.52 2.54 2.56 2.58 2.60

V, Ti Overlay
V-V$_2$O$_5$
Ti-ilmenite

V$_{K\alpha 1,2}$

Ti$_{K\beta}$

85

2.44 2.46 2.48 2.50 2.52 2.54 2.56 2.58

Composite $V_{K\alpha 1,2}$-$^{Ti}K_{\beta 1,3}$

L1F   300 cps.

$V_{K\alpha 1,2}$-chromite, C53-IN-8

$TiK_{\beta 1,3}$-ilmenite, Elliot Co.

$Ti_{K\beta 1,3}$

$V_{K\alpha 1,2}$

2.40   2.42   2.44   2.46   2.48   2.50   2.52   2.54   2.56   2.58   2.60
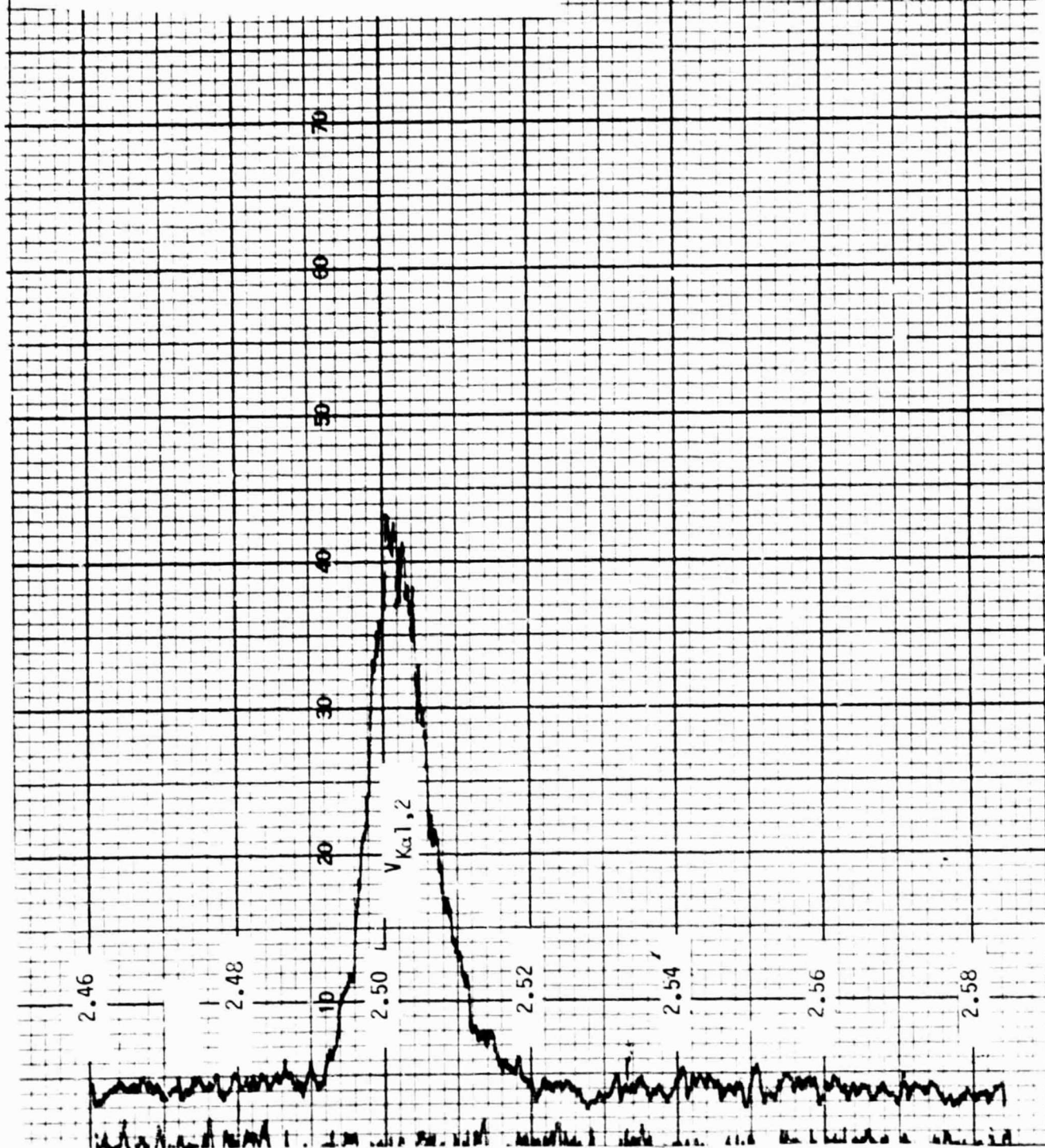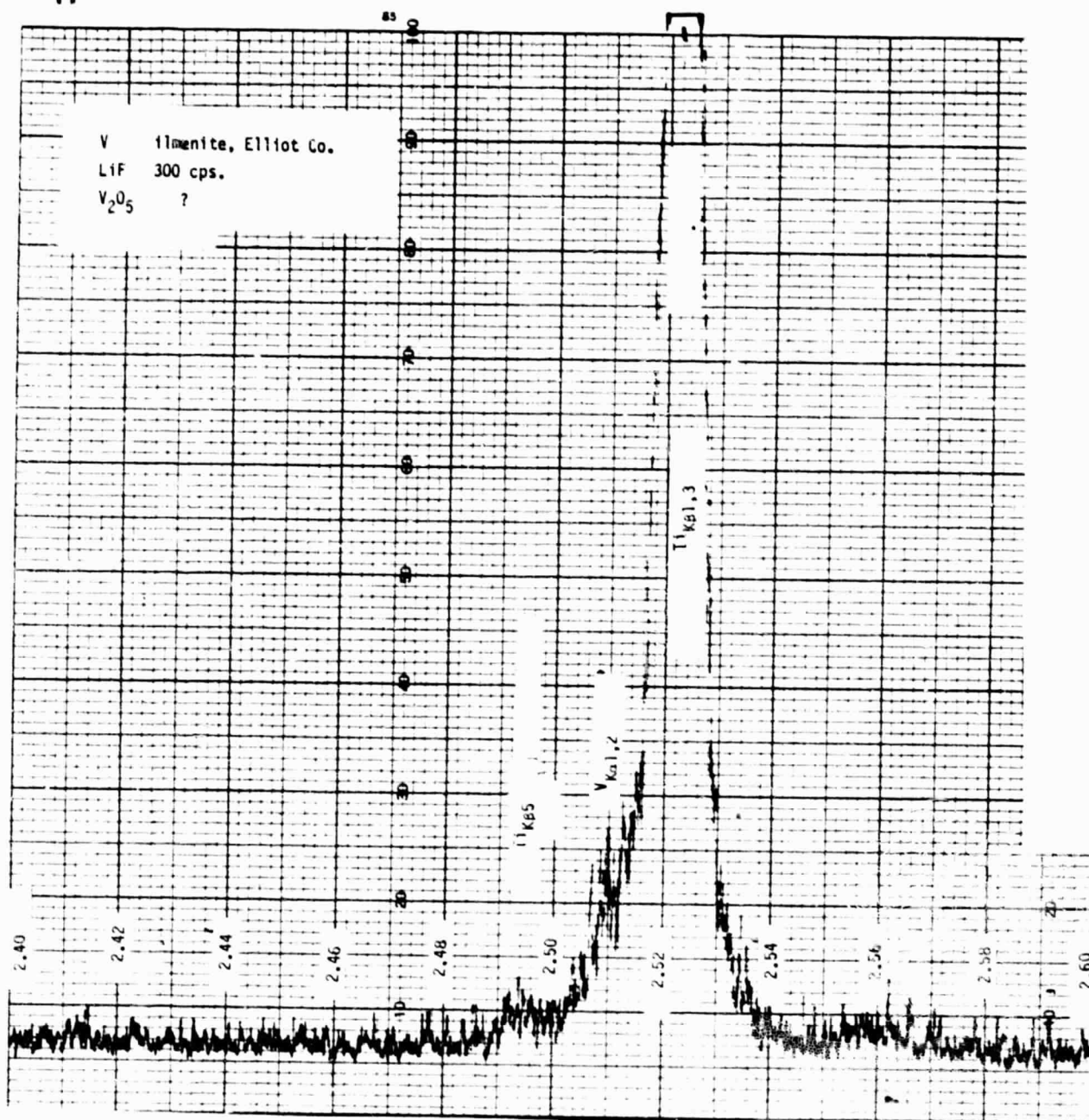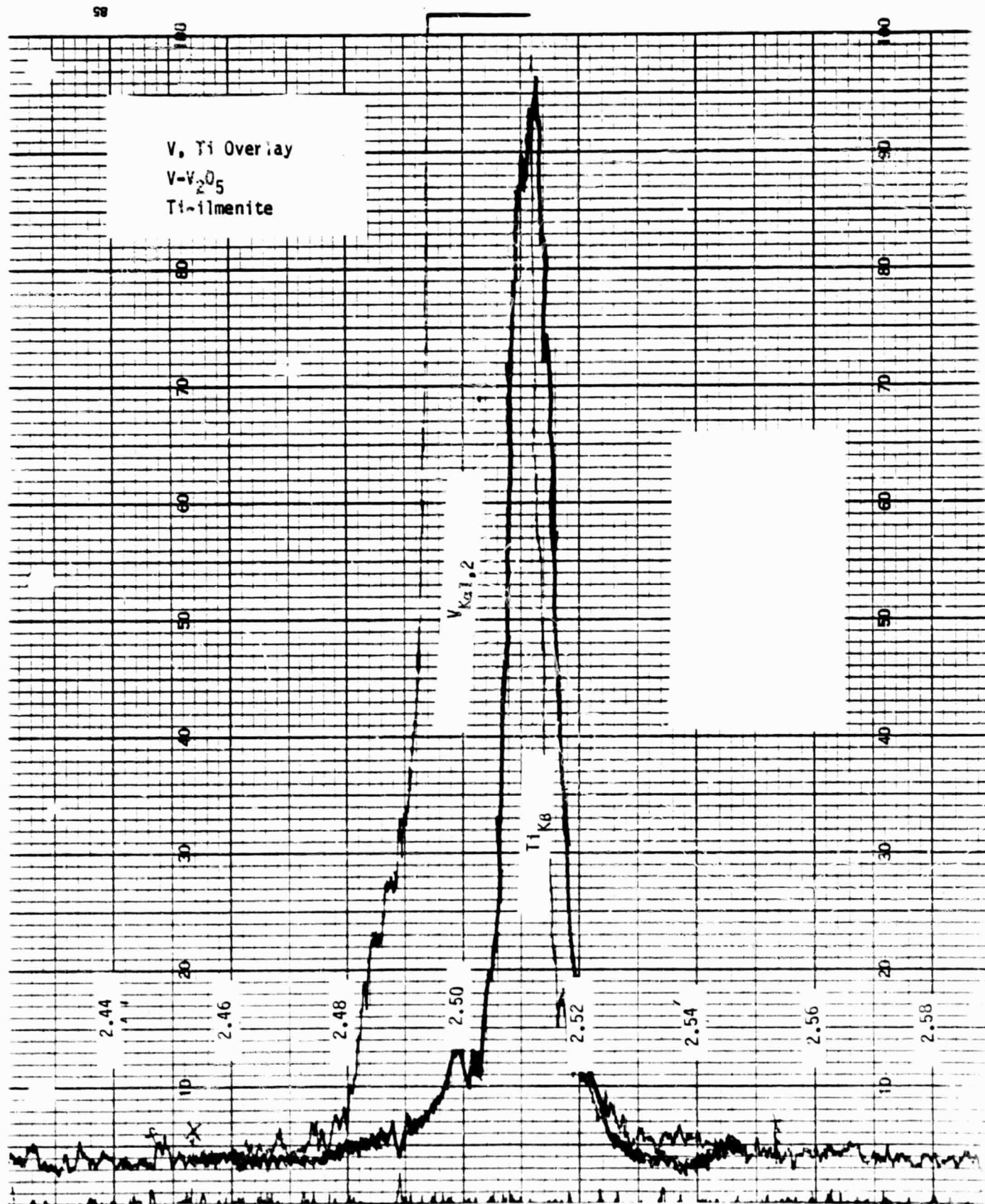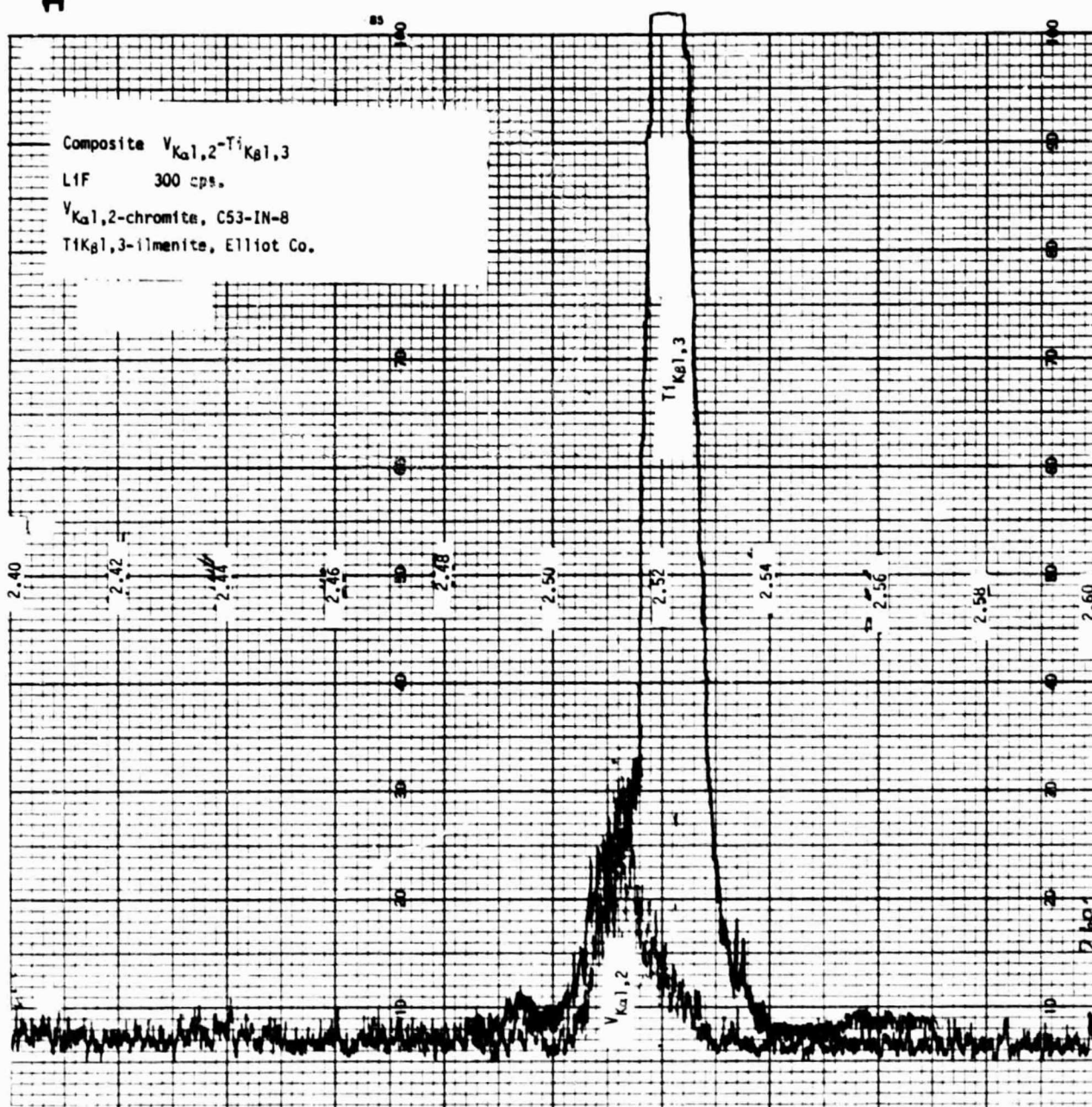
CHROMIUM

TABLE 24

ELEMENT: Cr

ANALYTICAL LINE: Kα1,2

CRYSTAL: LiF

SPECTROMETER SETTING: 2.291

BACKGROUND SETTING: ±0.064

ELEMENTAL SCANS:

MINERAL	WT % OXIDE	BACKGROUND SETTING
Chromite	38.76	±0.064
Armalcolite	6.69	±0.046

INTERFERENCES:

LINE	N	I	LiF (200)	KeV
Ba Lγ1	1	5	2.2415	5.53
Pr Lβ4	1	5	2.2550	5.50
Pr Lβ1	1	50	2.2588	5.49
V Kβ5	1	.02	2.2695	5.49
V Kβ1,3	1	20	2.2844	5.43
Cr Kα1,2	1	150	2.2910	5.41
La Lβ2,15	1	20	2.3030	5.38
Ba Lγ5	1	.1	2.3085	5.37
Ce Lβ3	1	6	2.3109	5.36
Ce Lβ4	1	5	2.3497	5.28
Ce Lβ1	1	50	2.3561	5.26

NOTES: Chromium in a high concentration of V, Ba, or REE may be a difficult
determination   because of the similar energies of all the
interfering X-ray lines. The use of a PHA as a discriminator is
hopeless.

FEET
LEFT

Cr   chromite
LiF   300 cps.
Cr_2O_3 38.76 wt. %

$Cr_{K\alpha1,2}$

58 FEET LEFT

Cr armalcolite
LiF 300 cps.
Cr_2O_3 6.69 wt. %

$Cr_{K\alpha1,2}$

$Zr_{K\alpha1,2}{}^{3rd}$

2.22
2.24
2.26
2.28
2.30
2.32
2.34
2.36
2.38
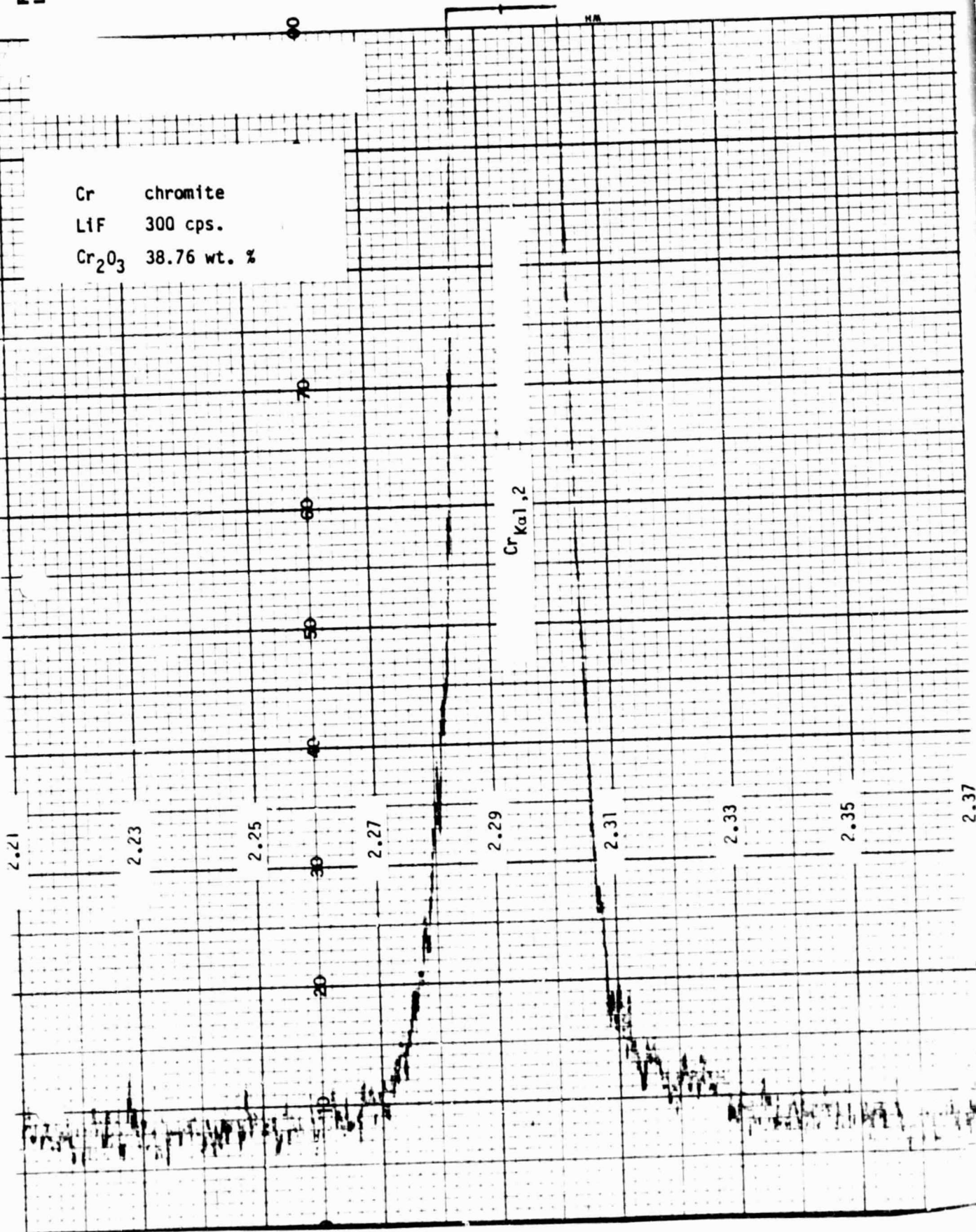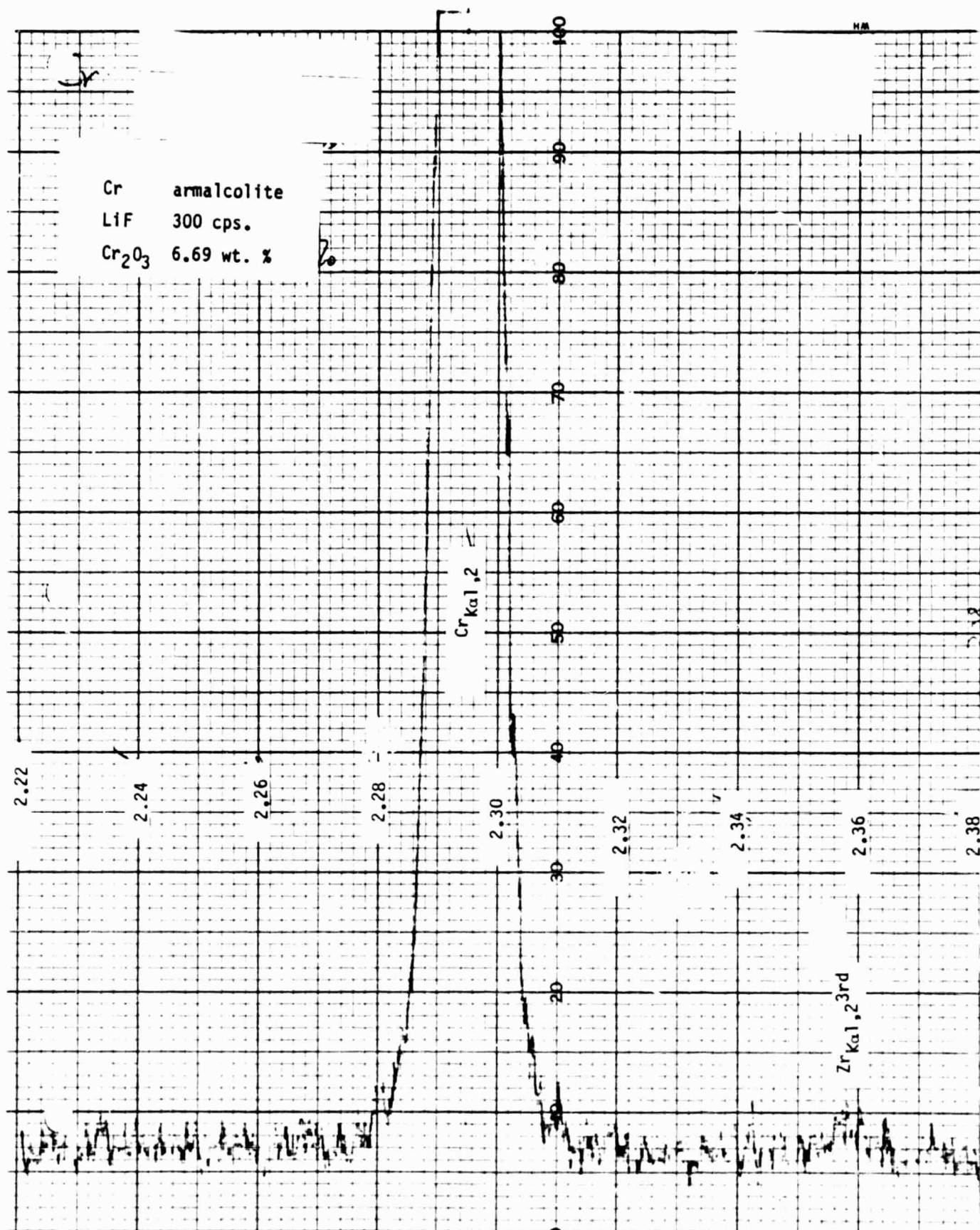
MANGANESE

TABLE 25

ELEMENT: Mn

ANALYTICAL LINE: Kα1,2

CRYSTAL: LiF

SPECTROMETER SETTING: 2.1031

BACKGROUND SETTING: ±.080 for Rhodonite; ±.030 low concentration samples

ELEMENTAL SCANS:

MINERAL	WT. % OXIDE	BACKGROUND SETTINGS
Rhodonite	40.77	±.080
Diopside	1.41	±.035
Chromite	0.17	Determination difficult

INTERFERENCES

LINE	N	I	LiF (200)	KeV
Nd Lβ2.15	1	20	2.0360	6.09
Gd Lα1	1	100	2.0468	6.06
Ce Lγ1	1	5	2.0487	6.05
Gd Lα2	1	10	2.0578	6.02
Cr Kβ1,3	1	18	2.0849	5.95
Mn Kα1,2	1	150	2.1031	5.89
Eu Lα1	1	100	2.1209	5.85
Nd Lβ3	1	6	2.1268	5.83
Eu Lα2	1	10	2.1315	5.82
Mo Kα1,2	3	150	2.1322	17.44
La Lγ1	1	5	2.1418	5.79
Nd Lβ4	1	5	2.1669	5.72
Nd Lβ1	1	50	2.1669	5.72

NOTES: Typically no interference problems except with a Cr-rich matrix, i.e., chromite, where CrKβ1,3 will interfere. PHA window is of no help.

Mn rhodonite
LiF 300 cps.
MnO 40.77 wt. %

Mn$_{K\alpha1,2}$

2.02 2.04 2.06 2.08 2.10 2.12 2.14 2.16 2.18 2.20 2.22
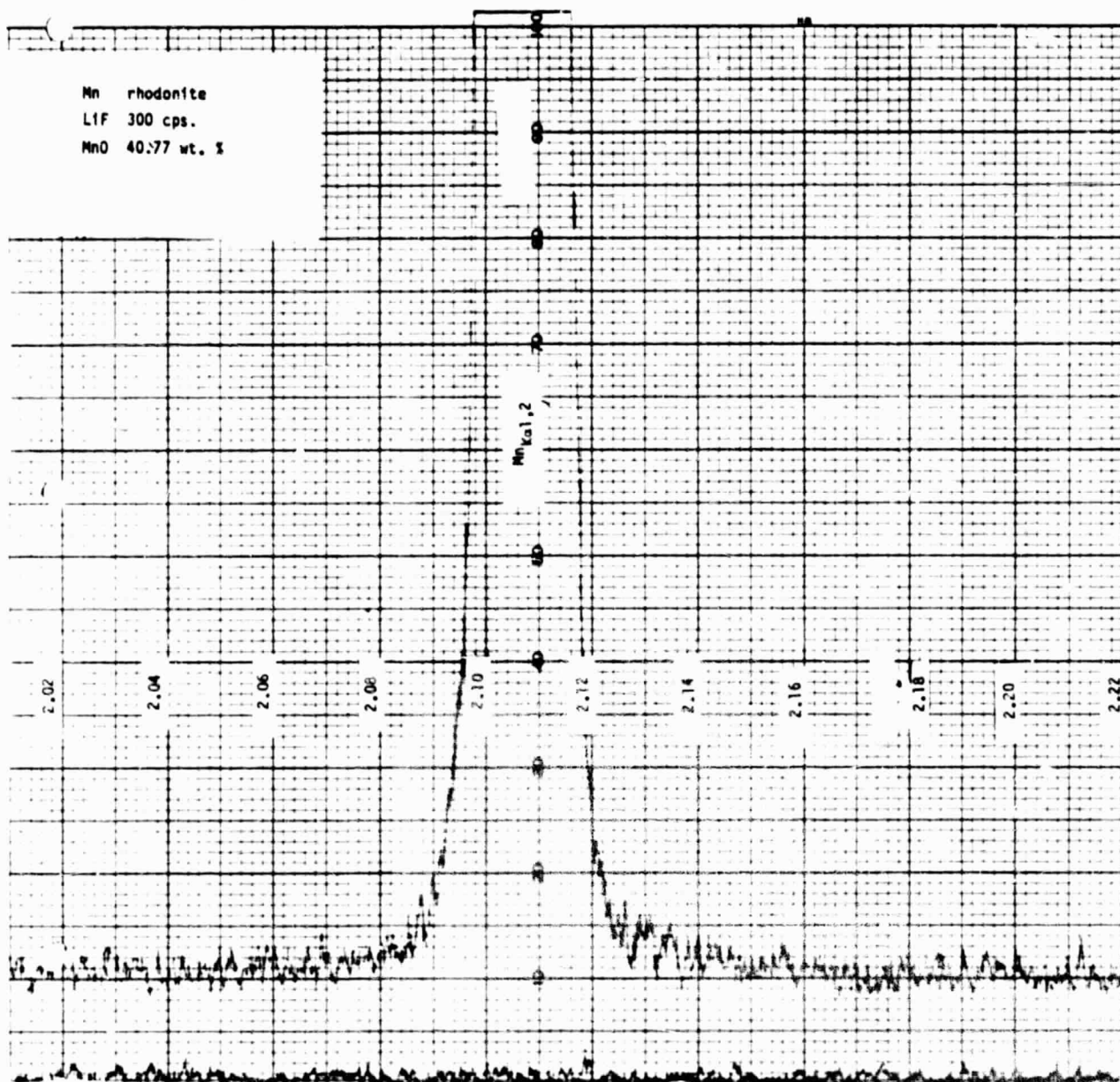
Mn   diopside glass doped with Cr, Mn, Ni.

LiF   300 cps.

MnO   1.41 wt. %

Cr   diopside

Cr, Mn   diopside

Mn chromite
L1F 300 cps.
MnO 0.17 wt. %
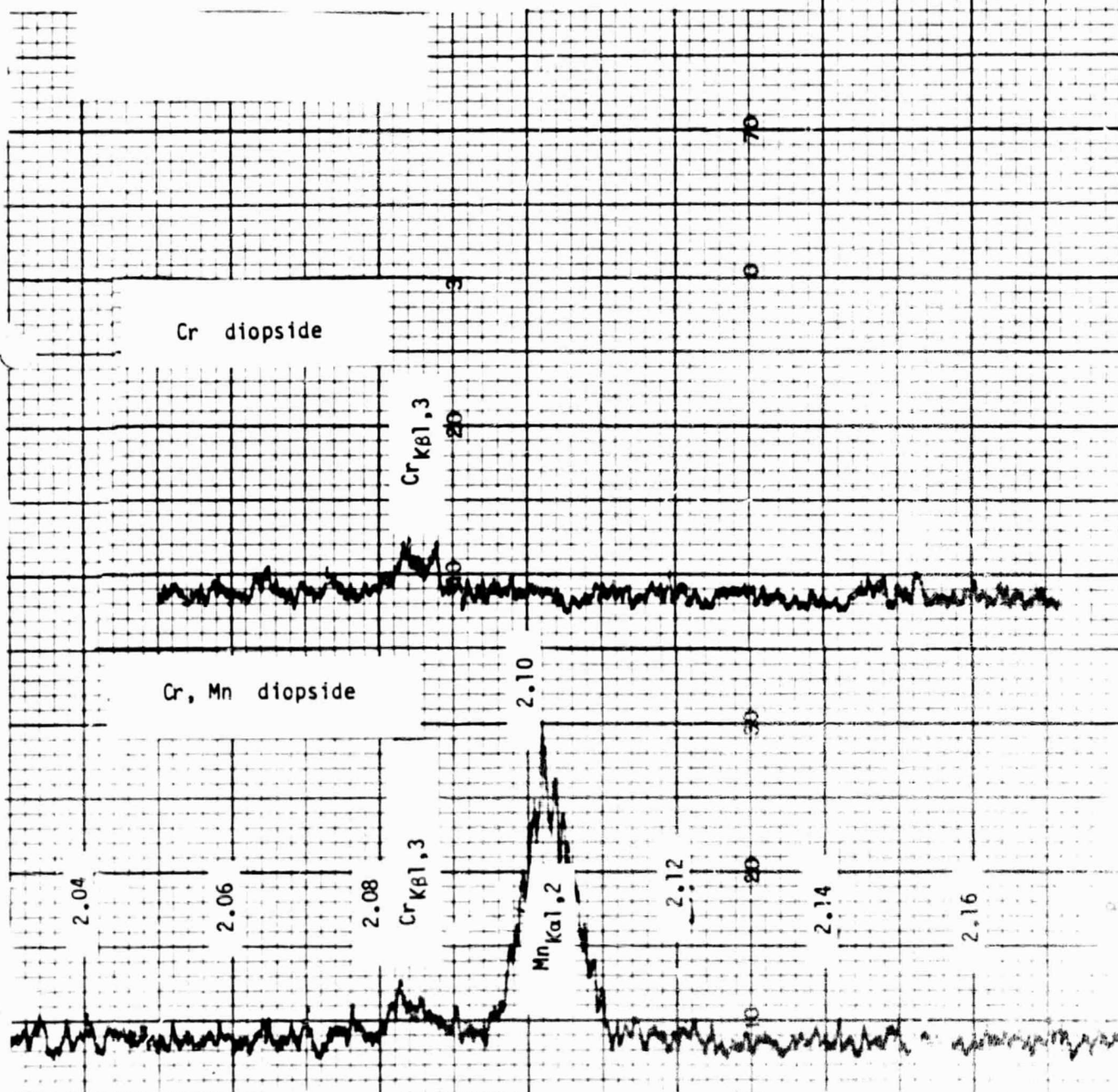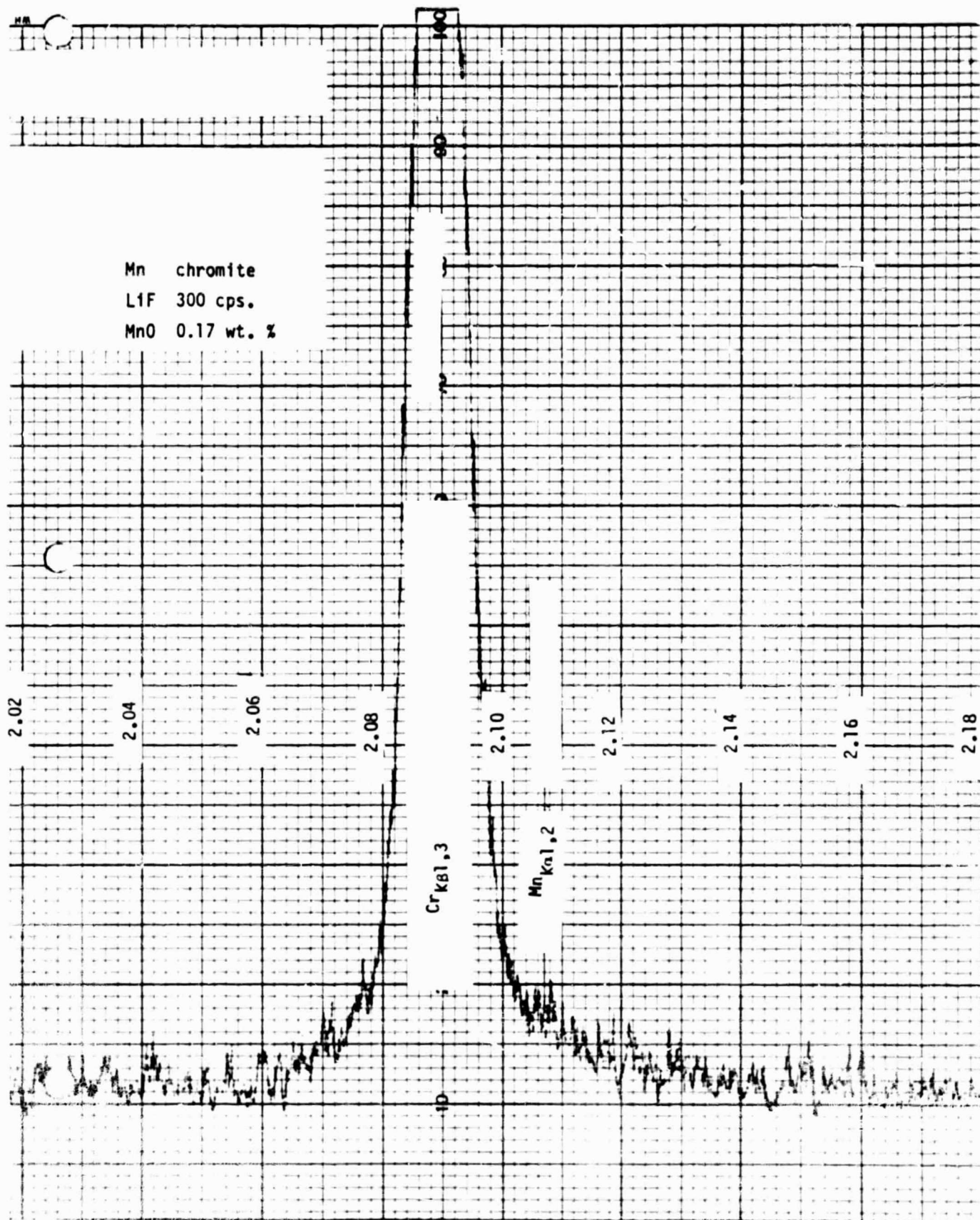
IRON

TABLE 26

ELEMENT: Fe

ANALYTICAL LINE: $K\alpha1,2$

CRYSTAL: LiF

SPECTROMETER SETTING: 1.937

BACKGROUND SETTING: ±0.062

ELEMENTAL SCANS:

MINERAL	WT.% OXIDE	BACKGROUND SETTING
CP19	8.49	±0.062
Rhodonite	3.60	±0.062

INTERFERENCES:

Line		N	I	LiF (200)	KeV
Nd	$L\gamma1$	1	5	1.8779	6.60
Pt	LV	2	.01	1.8786	13.20
Pt	$L\gamma8$	2	.1	1.8822	13.17
Pt	L_1-N_1	2	.01	1.8845	13.16
Eu	$L\beta3$	1	6	1.8867	6.57
Mo	$K\beta1$	3	17	1.8969	19.61
Mn	$K\beta5$	1	.03	1.8971	6.53
Mo	$K\beta3$	3	7	1.8986	19.59
DY	$L\alpha1$	1	100	1.9088	6.49
Mn	$K\beta1,3$	1	20	1.9102	6.49
Pt	$L\gamma1$	2	10	1.9159	12.94
Eu	$L\beta1$	1	50	1.9203	6.46
Eu	$L\beta4$	1	5	1.9255	6.44
Fe	$K\alpha1,2$	1	150	1.9374	6.40
Pt	L2-N3	2	.01	1.9443	12.75
Pt	L2-N2	2	.01	1.9584	12.66
Pr	$L\gamma1$	1	5	1.9611	6.32

Sm	Lβ3	1	6	1.9624	6.32
Pt	Lγ5	2	.1	1.9754	12.55
Tb	Lα2	1	10	1.9875	6.24
Sm	Lβ1	1	50	1.9981	6.20
Sm	Lβ4	1	5	2.0010	6.20

NOTES: Typically no problem except in a high Mn matrix. See rhodonite scan. Platinum lines are included for the benefit of experimental petrologists using Pt capsules.

Fe   clinopyroxene CP19
LiF   300 cps.
FeO   8.49 wt. %

$Fe_{K\alpha 1,2}$

1.86
1.88
1.90
1.92
1.94
1.96
1.98
2.00

FEET LEFT

Fe   rhodonite
LiF   300 cps.
FeO   3.60 wt. %
MnO   40.78 wt. %

Mn kβ1,3

Fe kα1,2

1.84
1.86
1.88
1.90
1.92
1.94
1.96
1.98
2.00
2.02
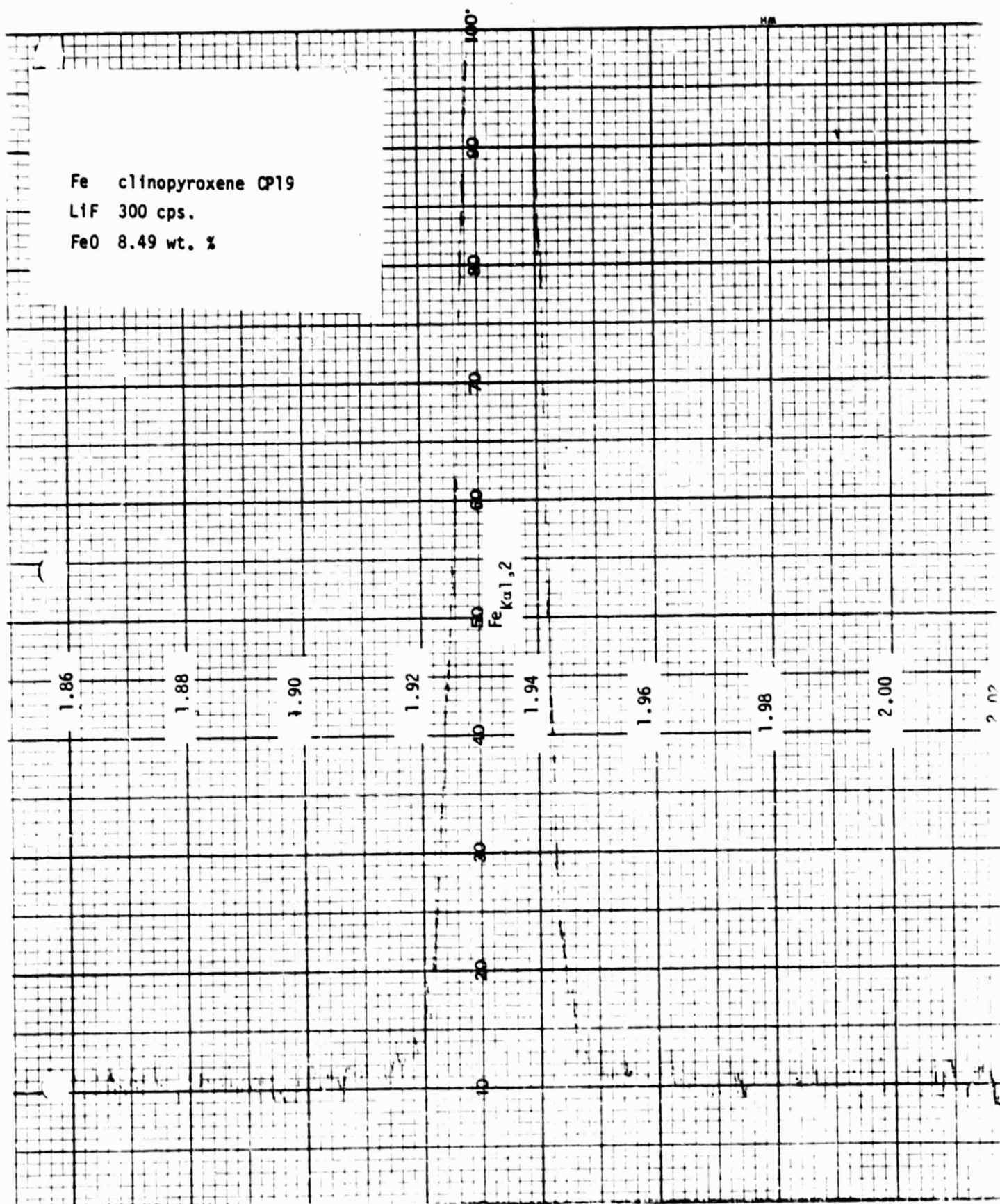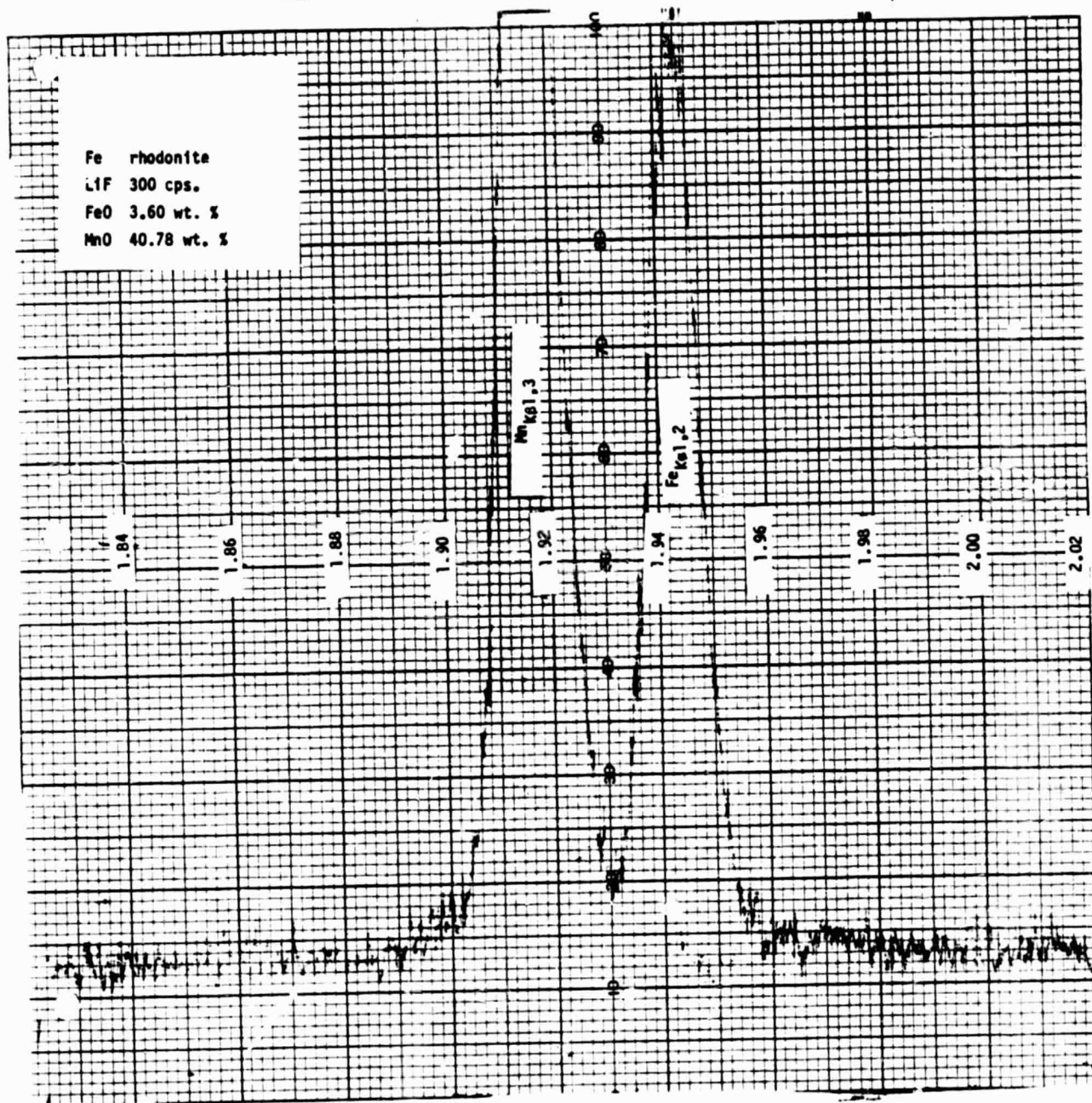
COBALT

TABLE 27

ELEMENT: Co

ANALYTICAL LINE: $K\alpha1,2$

CRYSTAL: LiF

SPECTROMETER SETTING: 1.7903

BACKGROUND SETTING: ±0.080

ELEMENTAL SCANS:

MINERAL	WT. %	BACKGROUND SETTING
Kamacite	----	±0.080
Co	99.9	±0.080

INTERFERENCES:

LINE		N	I	LiF (200)	KeV
Dy	$L\beta1$	1	50	1.7106	7.25
Sm	$L\gamma1$	1	5	1.7272	7.18
Fe	$K\beta5$	1	.03	1.7442	7.11
Sr	$K\alpha1,2$	2	150	1.7533	14.14
Fe	$K\beta1,3$	1	20	1.7566	7.06
Tb	$L\beta1$	1	50	1.7768	6.98
Er	$L\alpha1$	1	100	1.7843	6.95
Tb	$L\beta4$	1	5	1.7864	6.94
Co	$K\alpha1,2$	1	150	1.7903	6.92
Eu	$L\beta2,15$	1	20	1.8118	6.84

NOTES: Typically no problem except in a high Fe matrix. (See kamacite scan.) Undoubtedly there is some contribution to Co $K\alpha1,2$ from Fe $K\beta1,3$. Due to similar energies of the X-ray lines a PHA is not helpful. Best method of analysis would be to choose a standard with as similar composition as the sample as possible.

Co   Kamacite
Yamato   Meteorite
LiF 300 cps.

$Fe_{K\beta 1}$

$Co_{K\alpha 1,2}$

1.68 1.70 1.72 1.74 1.76 1.78 1.80 1.82 1.84 1.86

Co   99.9
LiF 300 cps.

$Co_{K\alpha 1,2}$

1.70
1.72.
1.74.
1.76.
1.78.
1.80.
1.82.
1.84.
1.86.
1.88.
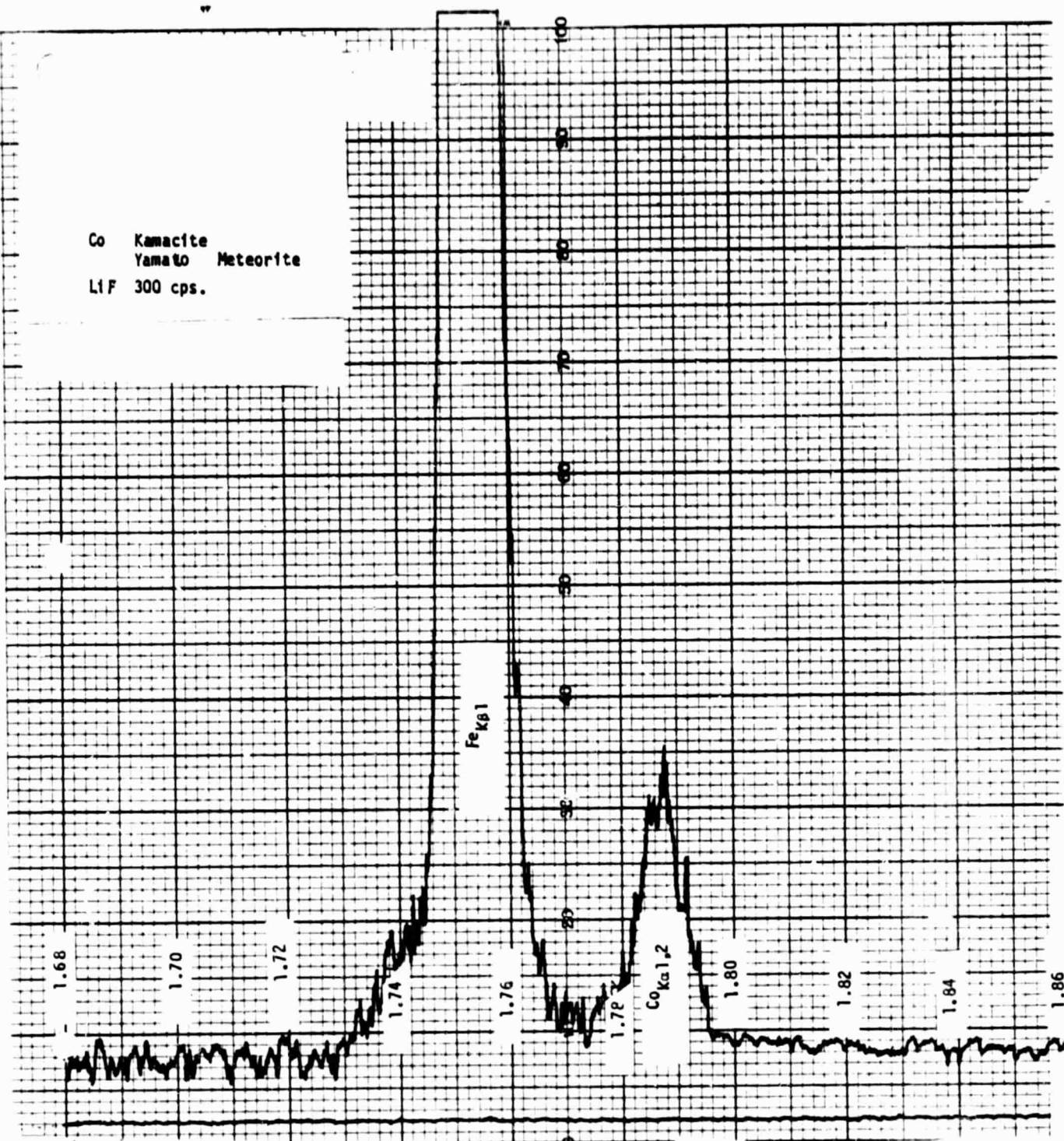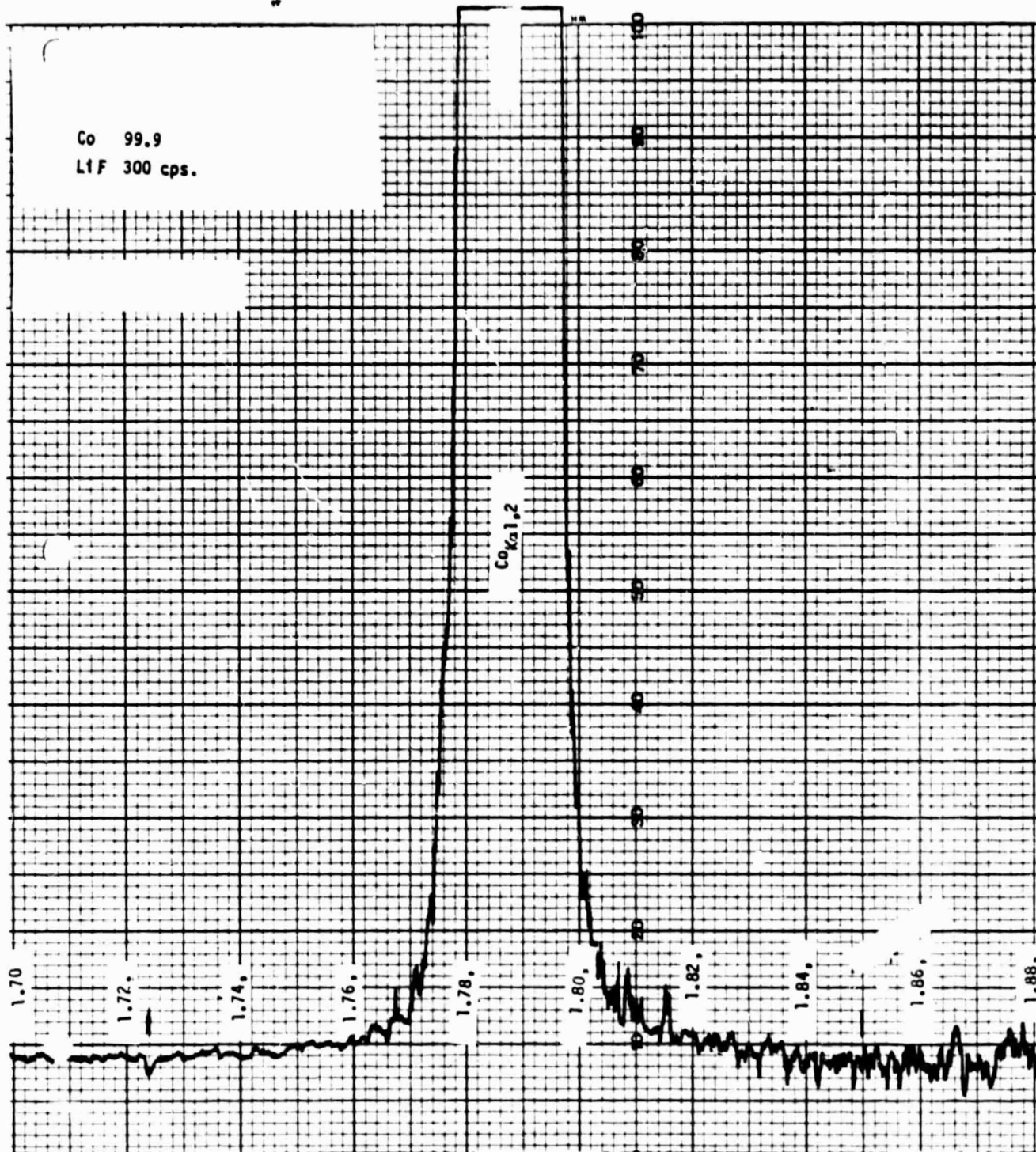
NICKEL

TABLE 28

ELEMENT: Ni

ANALYTICAL LINE: Kα1,2

CRYSTAL: LiF

SPECTROMETER SETTING: 1.6592

BACKGROUND SETTING: ±0.0065

ELEMENTAL SCANS:

MINERAL	WT. %	BACKGROUND SETTING
Ni (99.9)	—	±0.065
Fe85 Ni10 Co5	10.0 Ni	—
FeNi phase (Yamato Meteorite)	—	±0.029

INTERFERENCES:

LINE		N	I	LiF (200)	KeV
Er	Lβ4	1	5	1.6007	7.74
Co	Kβ5	1	.03	1.6089	7.71
Lu	Lα1	1	100	1.6195	7.65
Mo	Lβ3	1	6	1.6203	7.65
Co	Kβ1,3	1	20	1.6208	7.65
Dy	Lβ2,15	1	20	1.6237	7.63
Lu	Lα2	1	10	1.6303	7.60
Eu	Lγ1	1	5	1.6574	7.48
Ni	Kα1,2	1	150	1.6592	7.47
Ho	Lβ4	1	5	1.6595	7.47
Y	Kα1,2	2	150	1.6605	14.93
Yb	Lα1	1	100	1.6719	7.41

DY	Lβ3	1	6	1.6822	7.37
Ag	Kα1,2	3	150	1.6826	22.10
Yb	Lα2	1	10	1.6829	7.37
DY	Lβ1	1	50	1.7106	7.25
DY	Lβ4	1	5	1.7210	7.20
Tm	Lα1	1	100	1.7268	7.18

NOTES: Typically no problem although a high Co matrix may present an overlap problem due to tailing effects, but at the 5% Co level there does not appear to be a problem.

N1   99.9
L1F   300 cps.

N1$_{k\alpha 1,2}$

1.60   1.62   1.64   1.66   1.68   1.70   1.72   L74

85

Ni   Fe85 Ni10 Co5
LiF   300 cps.
Ni   10 wt.%

Ni Kα1,2

Co Kβ1,3

1.56   1.58   1.60   1.62   1.64   1.66   1.68   1.70   1.72

Ni   Yamato Meteorite

LiF   300 cps.

Ni Kα1,2

1.62   1.64   1.66   1.68   1.70   1.72
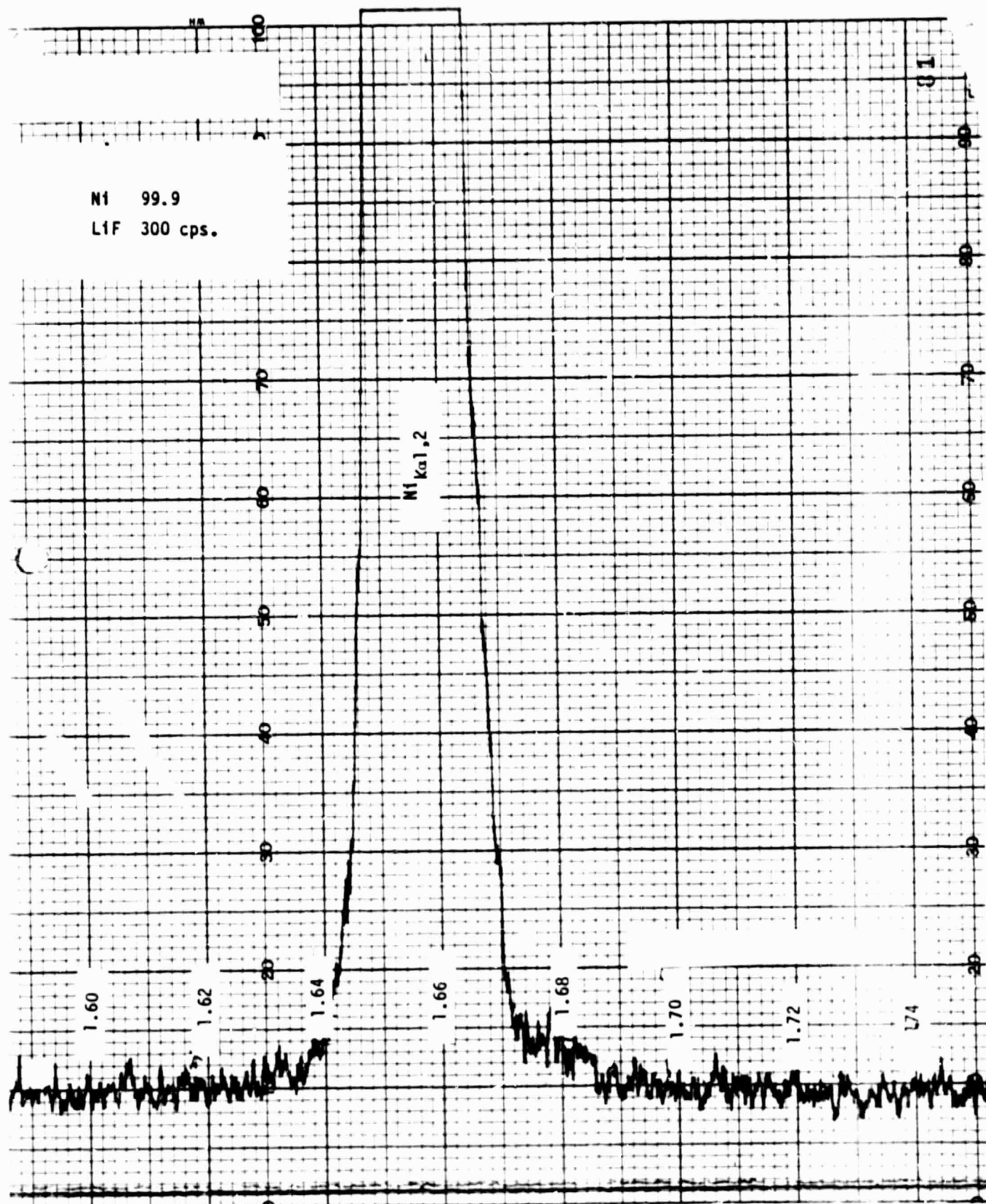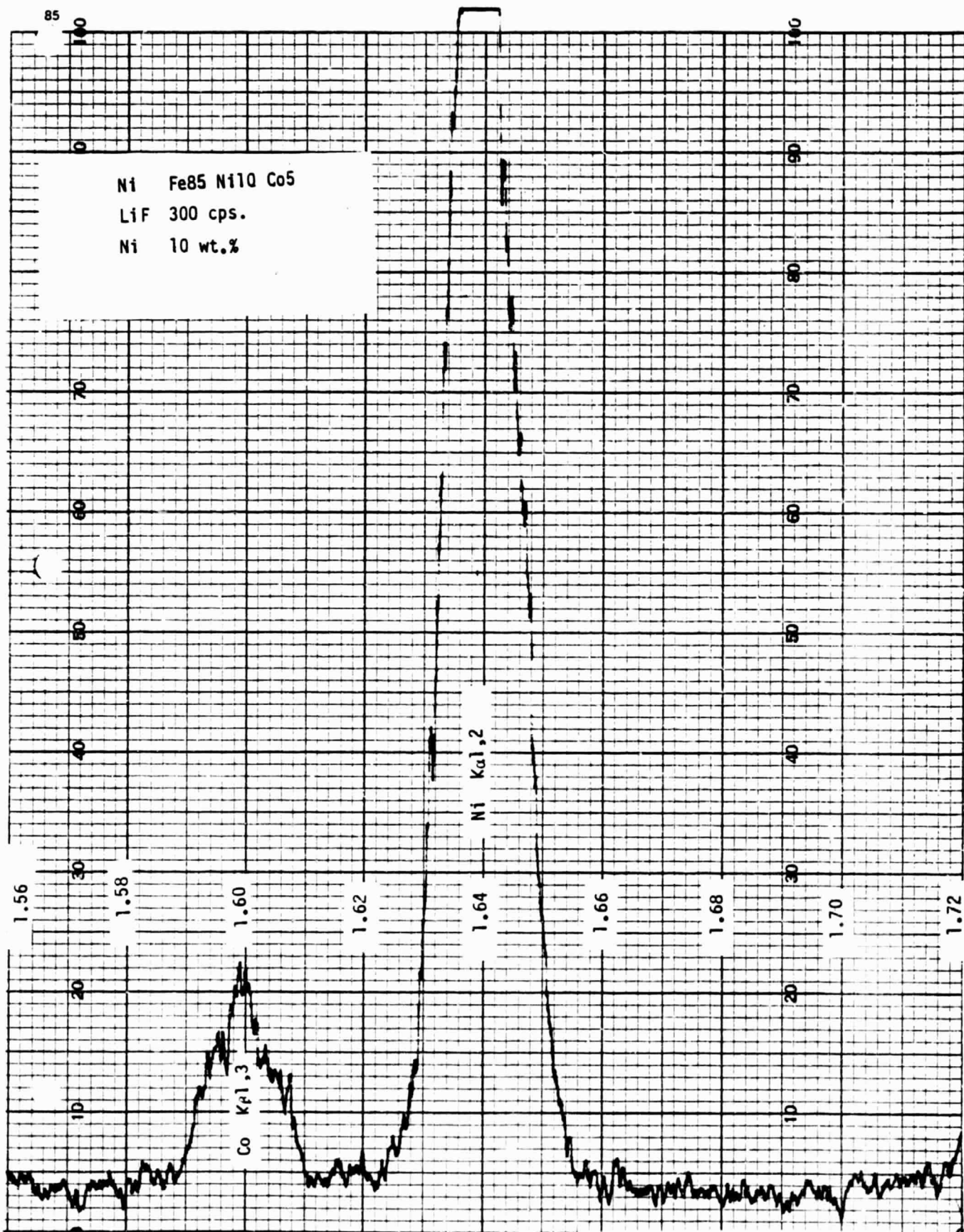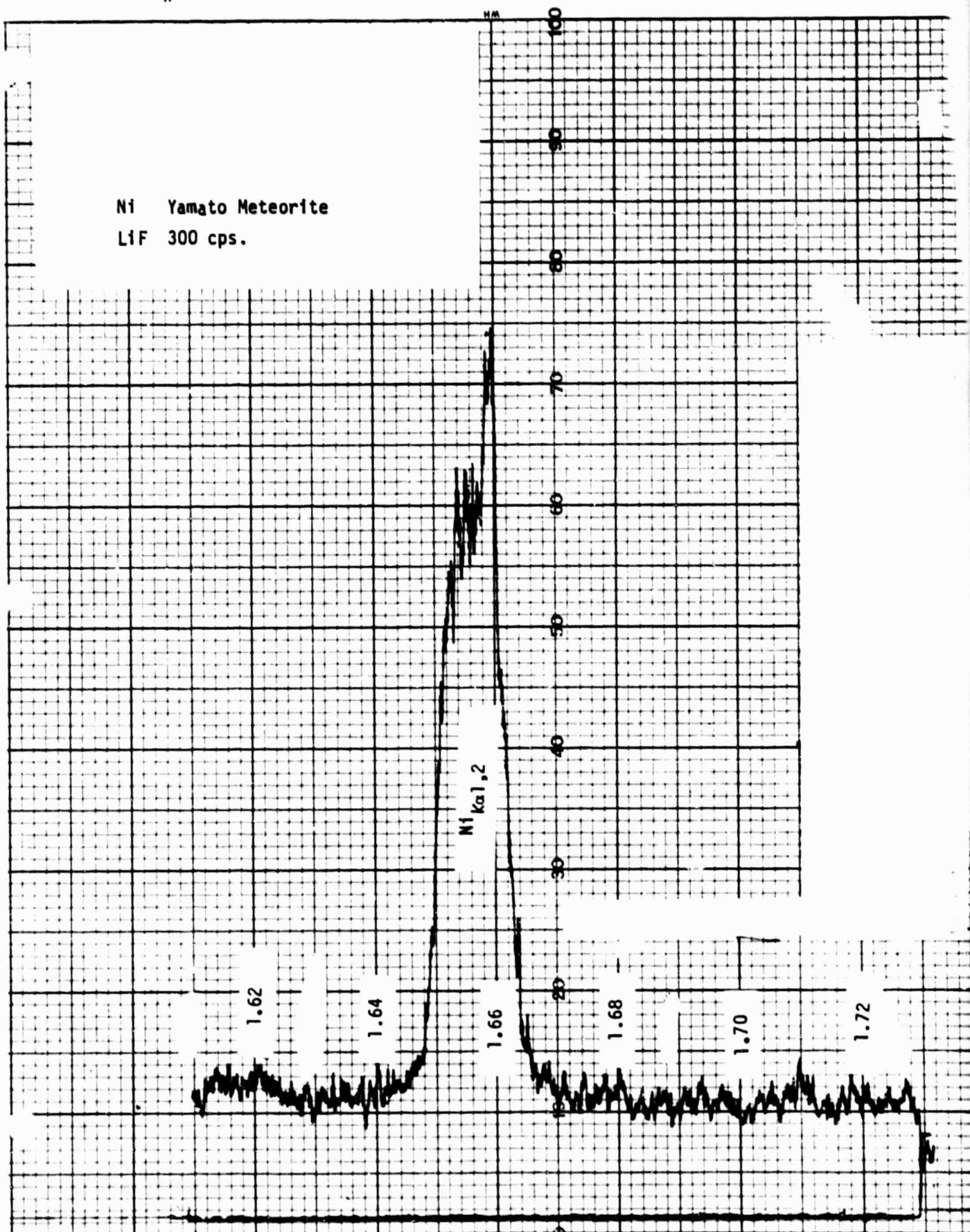
STRONTIUM

TABLE 38

ELEMENT: Sr

ANALYTICAL LINE: Lα1

CRYSTAL: ADP; PET

SPECTROMETER SETTING: 2.5972; 3.1610

BACKGROUND SETTING:

ELEMENTAL SCANS:

MINERAL	WT. % OXIDE	BACKGROUND SETTING
Lake County Plagioclase	600 ppm Sr	
Celestite	56.41	±0.046
Glass X (Probe Society)	0.80	

INTERFERENCES:

LINE	N	I	ADP (101)	PET (002)	KeV
Ca Kα1,2	2	150	2.5427	3.0948	3.69
Re Mα	1	100	2.5465	3.0994	1.84
Si Kβ	1	2	2.5556	3.1105	1.84
W Mβ	1	45	2.5571	3.1123	1.84
Lu Mγ	1	1	2.5613	3.1174	1.83
Si Kβ1	1	2	2.5651	3.1220	1.83
Rb Lβ3	1	3	2.5687	3.1264	1.83
Pb MZ2	1	.1	2.5741	3.1330	1.82
Si SKβ'	1	.1	2.5793	3.1394	1.82
Rb Lβ4	1	3	2.5812	3.1416	1.82
V Kβ1,3	3	20	2.5935	3.1566	5.43
Sr Lα1	1	100	2.5972	3.1610	1.81
Cr Kα1,2	3	150	2.6010	3.1657	5.41
Sb Lα1	2	100	2.6032	3.1684	3.60
K Kβ1,3	2	15	2.6142	3.1818	3.59
Zr LI	1	3	2.6183	3.1867	1.79
W Mα1	1	100	2.6426	3.2164	1.78

Rb Lβ6	1	3	2.6431	3.2169	1.78
W Mα2	1	100	2.6461	3.2205	1.77
Si SKα6	1	.1	2.6566	3.2334	1.77
Ta Mβ	1	45	2.6578	3.2348	1.77
Yb Mγ	1	1	2.6582	3.2353	1.77
Fe Kβ1,3	4	20	2.6591	3.2364	7.06
Si SKα5	1	.2	2.6603	3.2378	1.76
Si SKα4	1 ·	3	2.6743	3.2549	1.75
Rb Lβ1	1	45	2.6778	3.2592	1.75
Si SKα3	1	6	2.6781	3.2596	1.75
Si SKα'	1	.5	2.6848	3.2677	1.75
Si SKα1,2	1	150	2.6969	3.2824	1.74

NOTES: Sr occurs at the trace level in silicates such as feldspars and
clinopyroxenes and rarely occurs as a major constituent except
in some SO_4 and CO_3 phases. At trace levels the adjacent Si SK
line causes a background as well as an overlap problem and
background position should be chosen on the high angle side only.
The energy of the Si SK line is identical to the Sr Lα line and
therefore use of a PHA is hopeless. Better PK/BKg ratio can be achieved
by using an electron beam of 30KV rather than 15KV acceleration potential.

FEET LEFT

Sr   Lake County Plagioclase
ADP   100 cps.
Sr   ~600 ppm
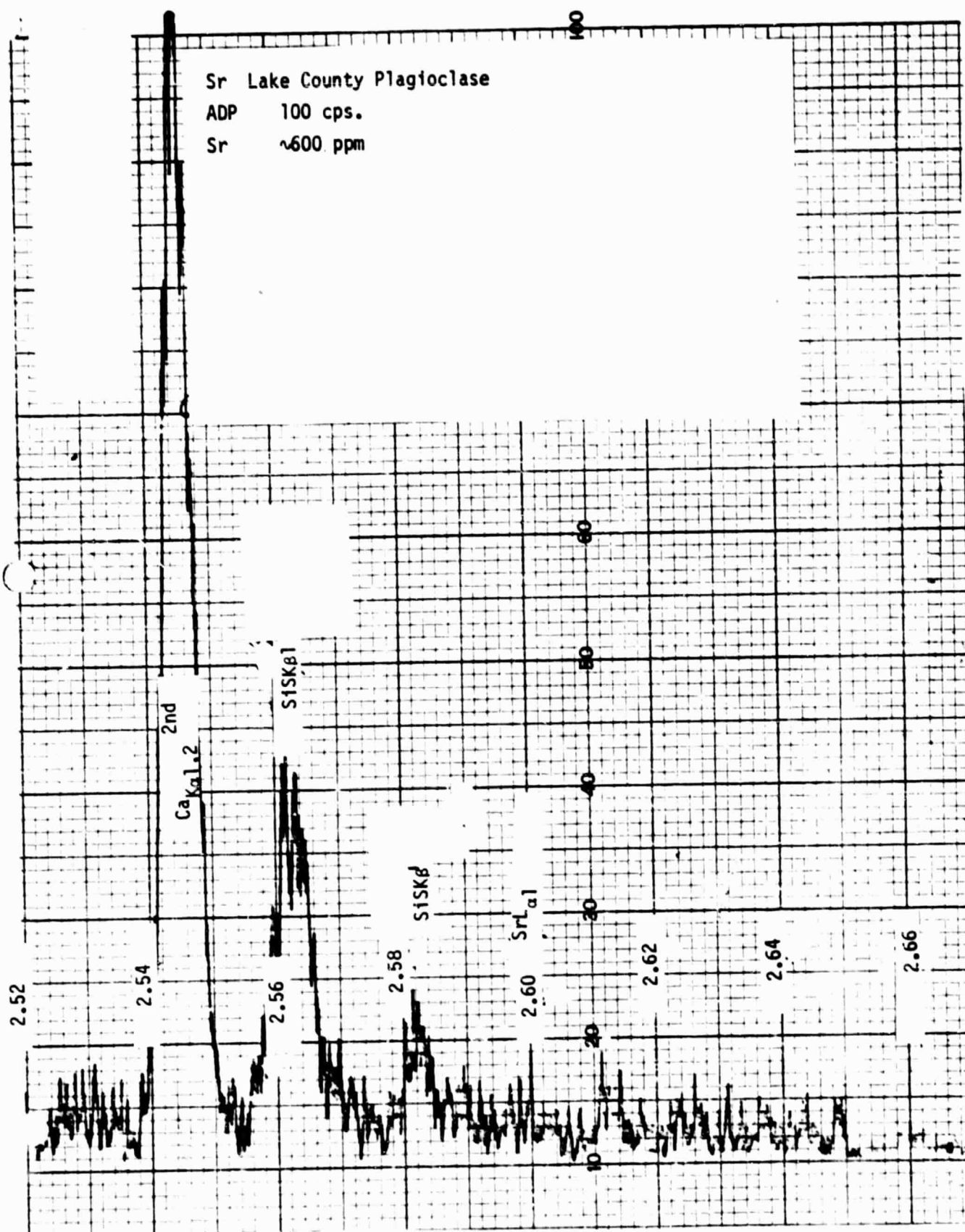
FEET LEFT

Sr   CELESTITE
ADP   300 cps.
SrO   56.41 wt. %

$SrL_{\beta 1}$

$SrL_{\alpha 1}$

?

2.50 2.52 2.54 2.56 2.58 2.60 2.62 2.64 2.66
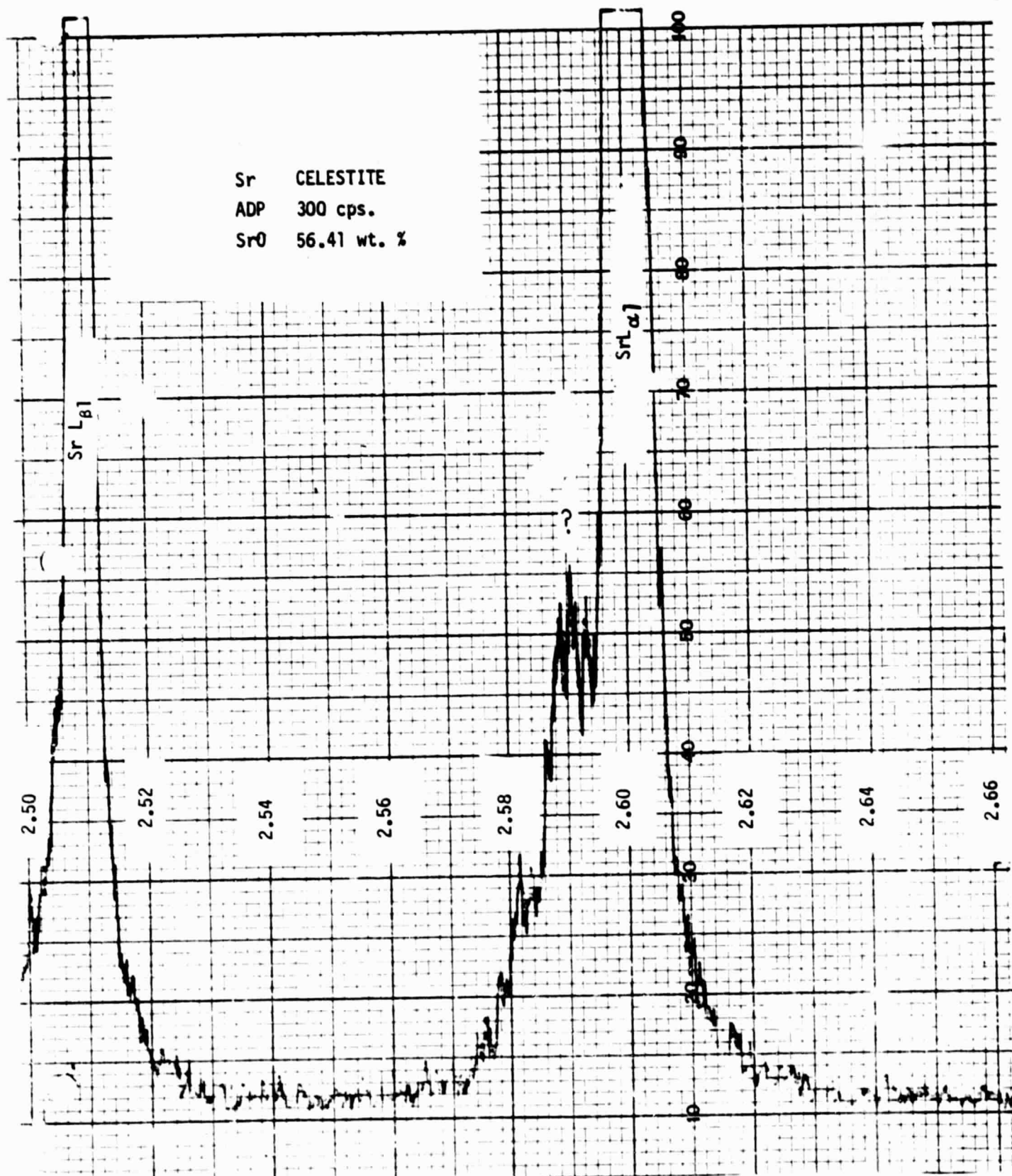
Sr GLASS X (Probe Society)
ADP   100 cps.
SrO   0.80

Si SKβ₁

2.54

2.56

2.58

2.60

2.62

2.64

2.66

Si SKβ'

SrLα₁
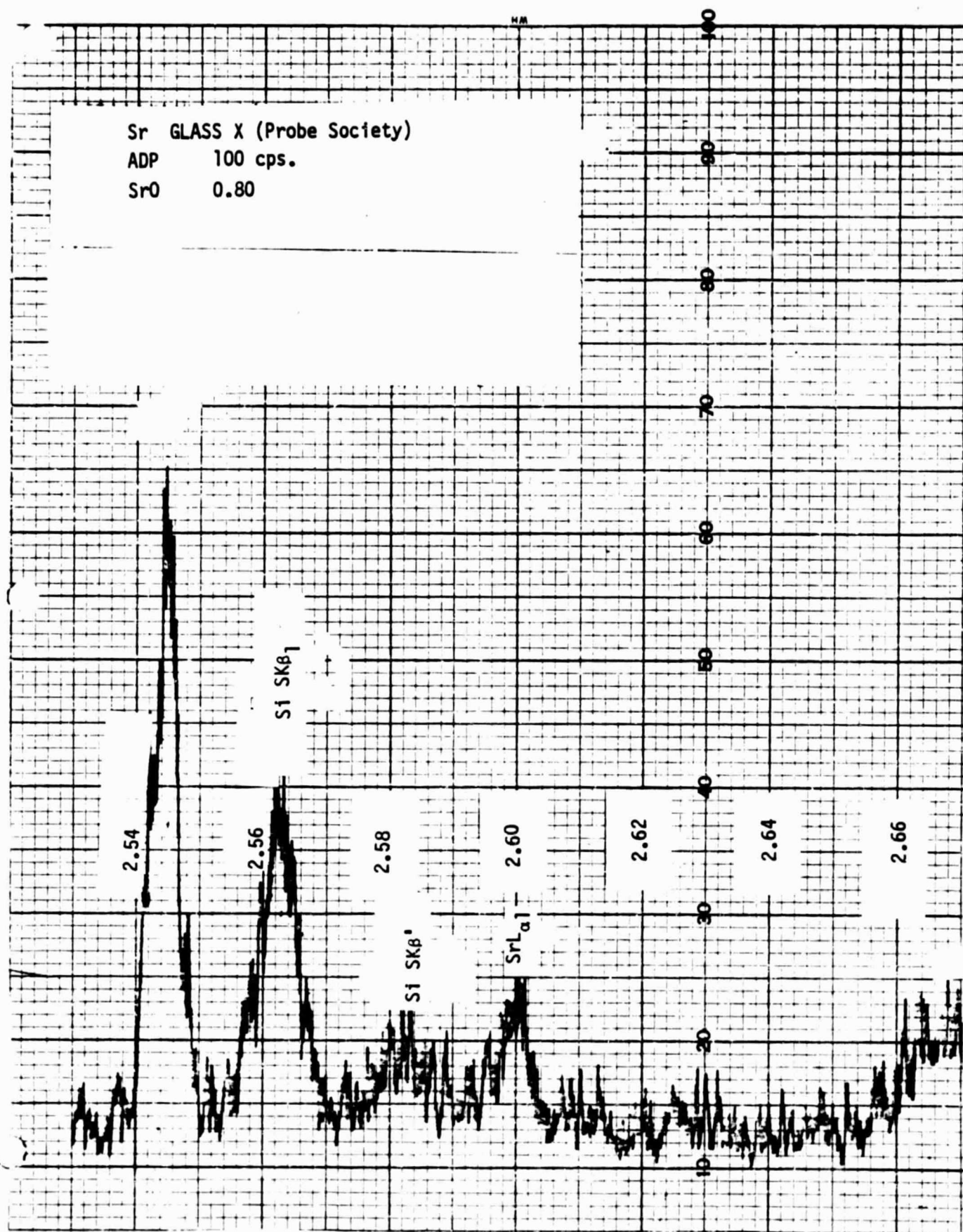
ZIRCONIUM

TABLE 40

ELEMENT: Zr

ANALYTICAL LINE: Zr Lα1,2

CRYSTAL: PET, ADP

SPECTROMETER SETTING: 2.7961; 2.2973

BACKGROUND SETTING: ▶ ±0.060

ELEMENTAL SCANS:

MINERAL	WT.% OXIDE	BACKGROUND SETTING
zircon	67.27	±0.060
armalcolite	6.31	±0.030

INTERFERENCES:

LINE	N	I	PET (002)	ADP (101)	KeV
Y Lβ3	1	3	2.7559	2.2643	2.07
Pt M5-O3	1	.01	2.7576	2.2657	2.07
Sm Lβ1	3	50	2.2684	2.7609	6.20
Ni Kβ1,3	4	20	2.7639	2.2708	8.26
Y Lβ4	1	3	2.7722	2.2777	2.06
Rb Lγ2,3	1	.1	2.7847	2.2880	2.05
Pt Mα1	1	100	2.7853	2.2884	2.05
Er Lβ2,15	4	20	2.7894	2.2918	8.19
Pt Mα2	1	100	2.7903	2.2926	2.05
P SKα6	1	.01	2.7927	2.2946	2.04
Sc Kα1,2	2	150	2.7931	2.2949	4.09
Zr Lα1	1	100	2.7961	2.2973	2.04
P SKα5	1	.01	2.7983	2.2991	2.04
Zr Lα2	1	10	2.7995	2.3001	2.04
Ta Lα1	4	100	2.8041	2.3039	8.15
Y Lβ6	1	3	2.8070	2.3063	2.03
Nd Lβ2,15	3	20	2.8134	2.3115	6.09

P Skα4	1	5	2.8137	2.3118	2.03
P Skα3	1	5	2.8173	2.3148	2.03
Tm Lβ1	4	50	2.8196	2.3167	8.10
P SKα'	1	.5	2.8239	2.32͟2	2.02
Gd Lα1	3	100	2.8283	2.3238	6.06
P Kα1,2	1	150	2.8364	2.3304	2.01
Ca Kβ1,3	2	15	2.8463	2.3385	4.01

NOTES: Chief source of interference with   Zr determination is P SKα5. Although
of low intensity it occurs at the same position and is the same energy
as the Zr Lαl therefore   a PHA is not helpfull. Aside from P the
REE Sm, Er, Nd, Tm and Gd all have x-ray peaks within the background
region but can be discriminated against with a PHA. Ca Kβ1,3 is probably
far enough away so as not to present a problem.

Zr   Zircon
PET   300 cps.
ZrO_2 67.27 wt. %

$Zr_{L\beta3}$

$Zr_{L\beta4}$

$Zr_{L\beta1}$

$Zr_{L\alpha1,2}$

85

FEET
LEFT
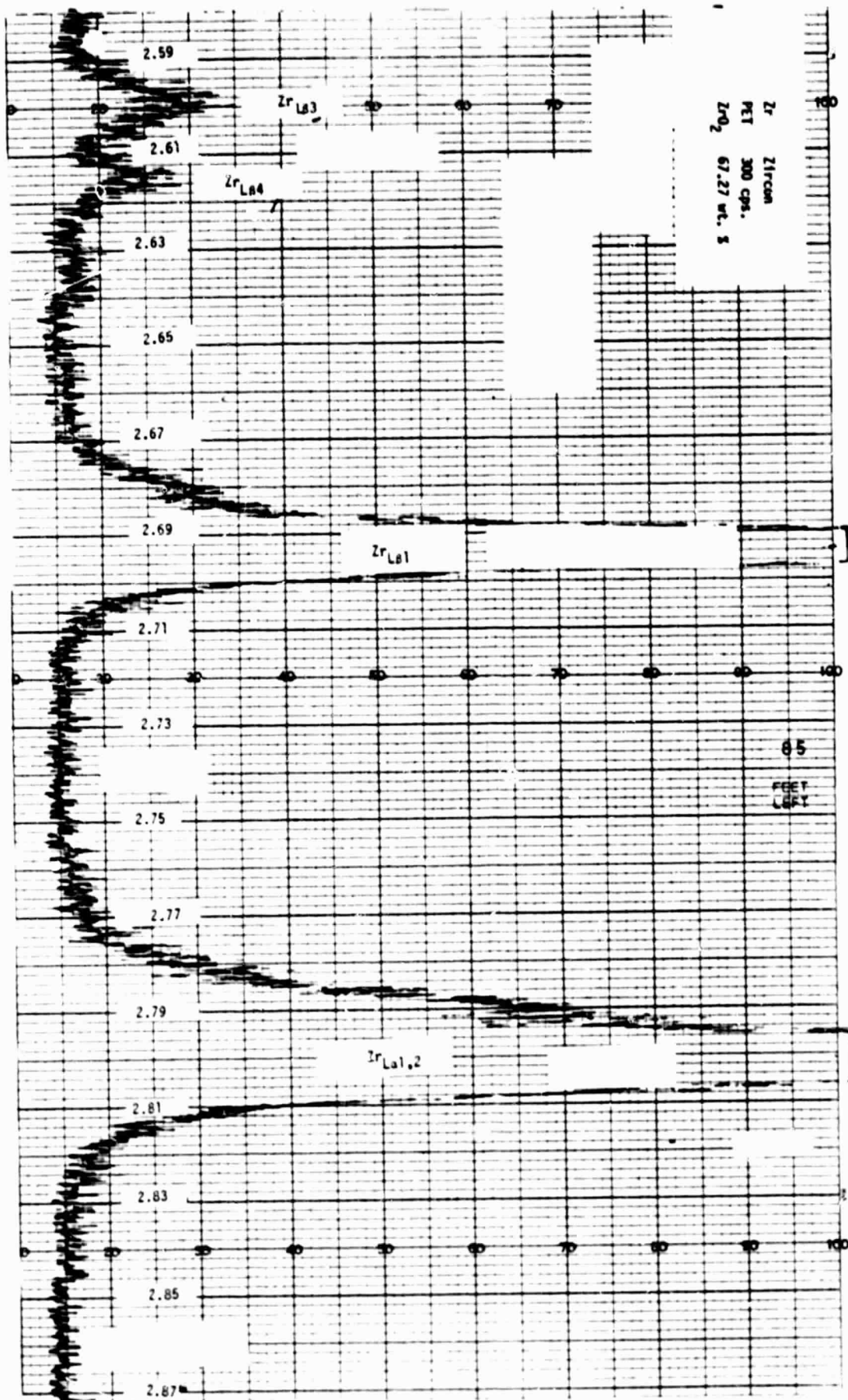
Zr   Armalcolite
ADP   300 cps.
ZrO_2 6.31 wt. %
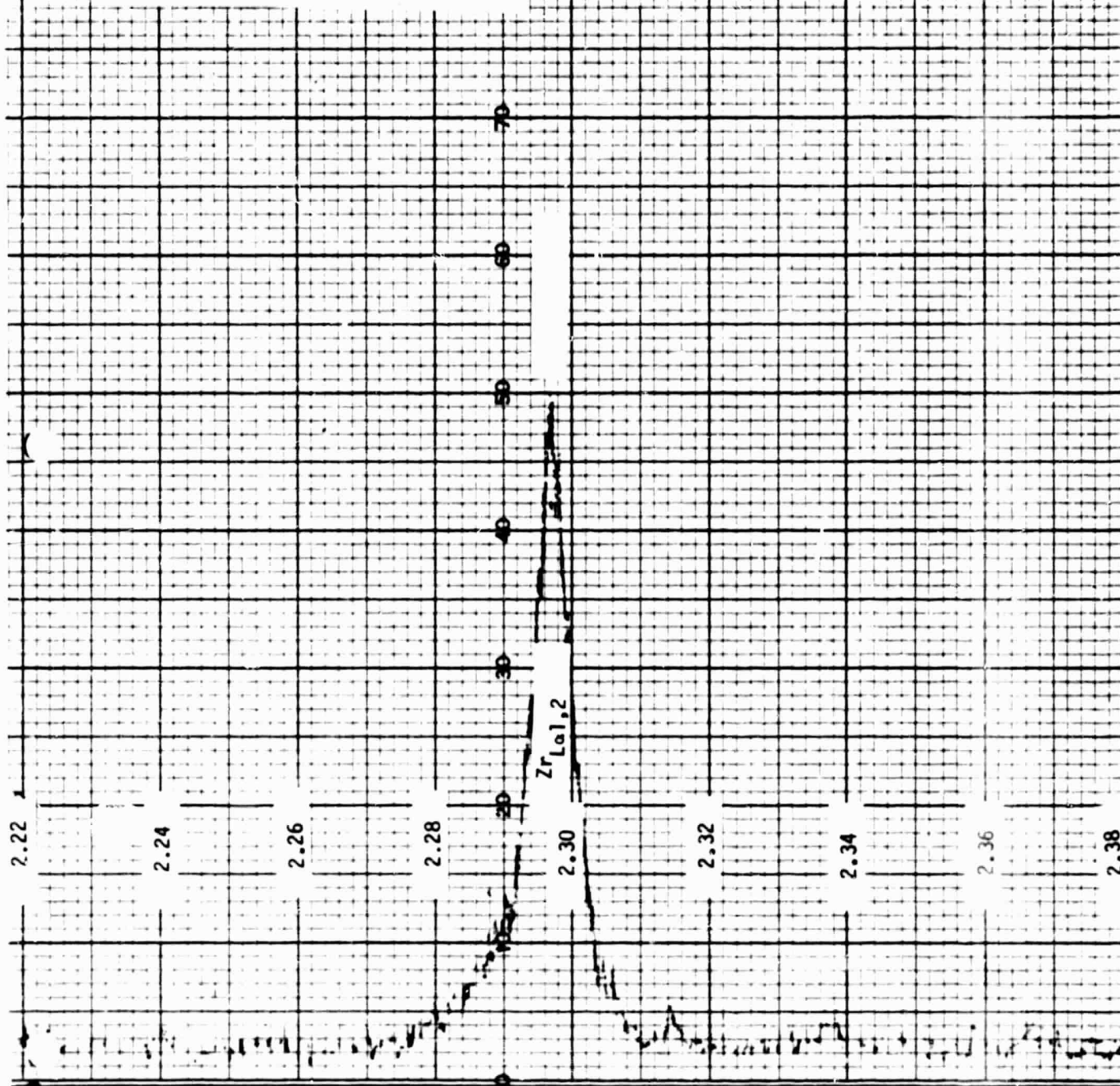
$Zr_{L\alpha1,2}$

2.22 2.24 2.26 2.28 2.30 2.32 2.34 2.36 2.38

BARIUM

TABLE 56

ELEMENT: **Ba**

ANALYTICAL LINE: Lα1

CRYSTAL: LiF (200)

SPECTROMETER SETTING: 2.7760

BACKGROUND SETTING: +0.056

ELEMENTAL SCANS:

MINERAL	WT % OXIDE	BACKGROUND SETTING
Barite	65.69	+0.056
Benitoite		

INTERFERENCE:

	LINE	N	I	LiF (200)	KeV
Er	Lα1	2	5	2.7282	9.09
Ti	Kα1,2	1	150	2.7497	4.51
Zr	KB2	4	4	2.7597	17.97
Ba	Lα1	1	100	2.7760	4.47
Rb	Kα1,2	3	150	2.7808	13.37
Cu	KB1,3	2	20	2.7844	8.90
Cu	KB3	2	6	2.7852	8.90
Ba	Lα2	1	10	2.7855	4.45
Zr	KB1	4	18	2.8069	17.67
Zr	KB3	4	9	2.8091	17.65

NOTES: Barium typically occurs as a minor to trace level constituent
in feldspars and as a major component of some carbonates,
sulfates and halides. There should be little or no interference
on the BaLα1 line with the exception of TiKα1,2 which is of such
similar energy (see TABLE) that use of a PHA will not discriminate
against it.

Ba   benitoite
LiF 300 cps.
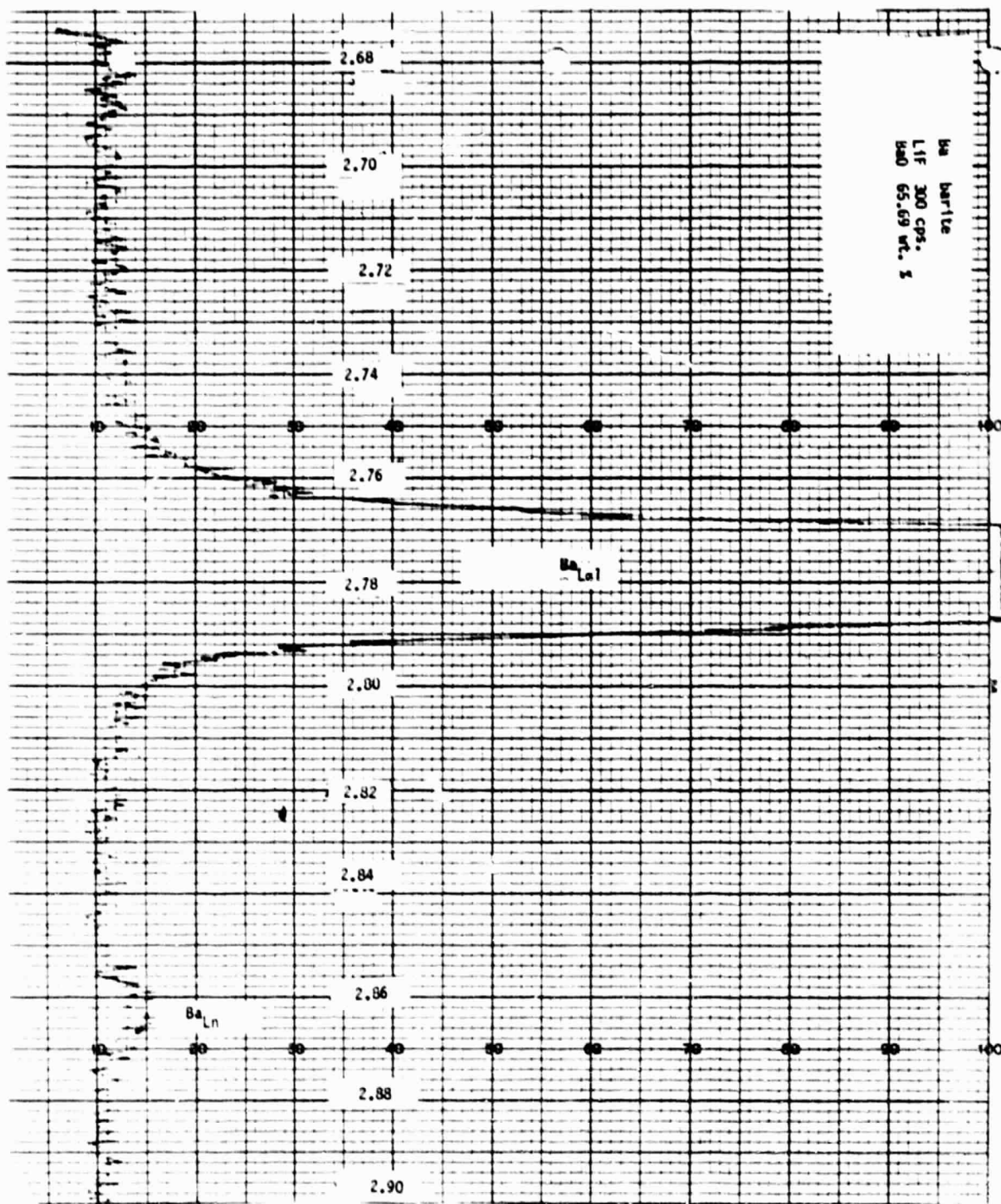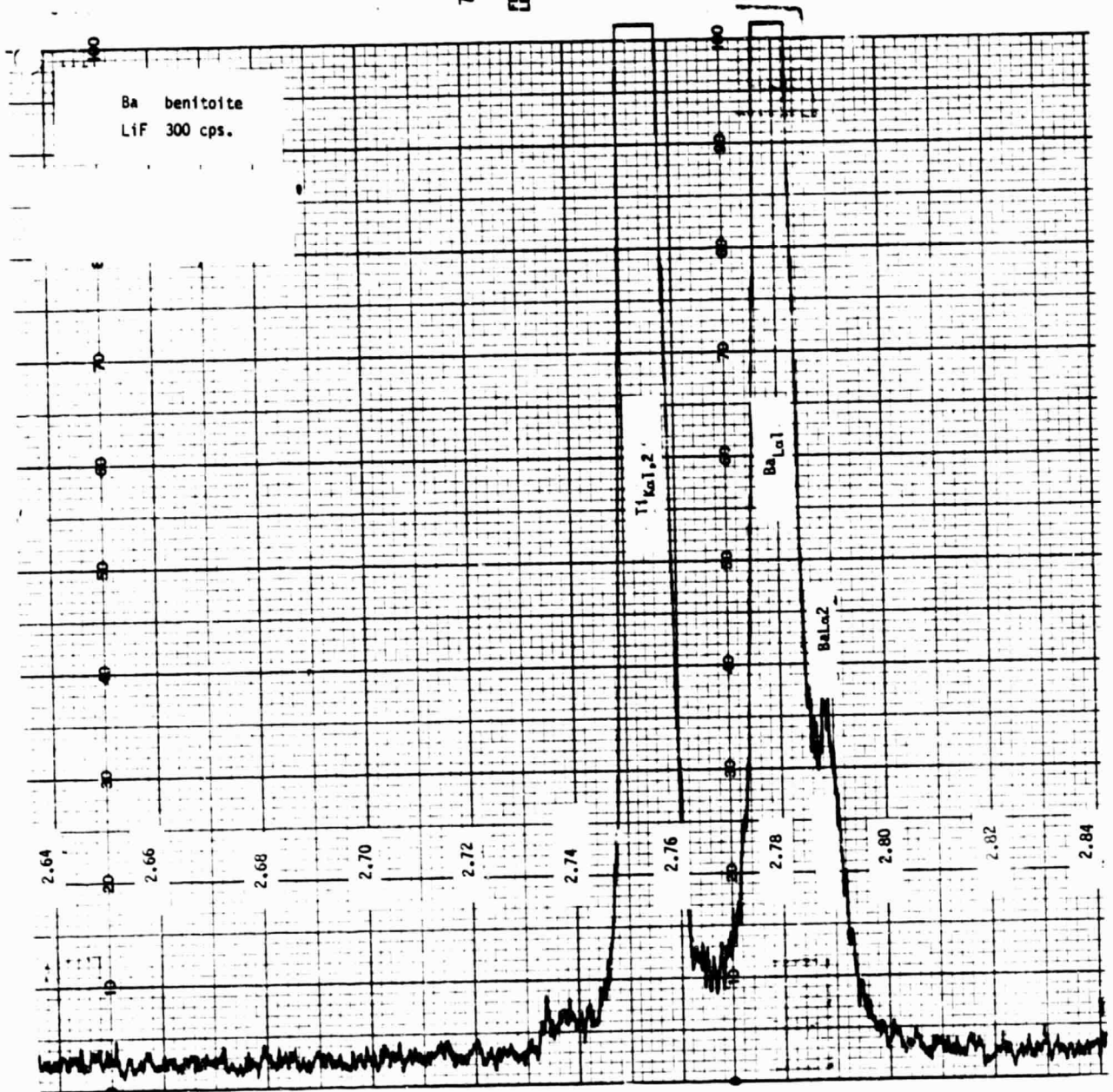
LANTHANUM

TABLE 57

ELEMENT: La

ANALYTICAL LINE: Lα1

CRYSTAL: LiF

SPECTROMETER SETTING: 2.6657

BACKGROUND SETTING:

ELEMENTAL SCANS:

MINERAL	WT % OXIDE	BACKGROUND SETTING
Glass REE 3	4.28	±0.027
Perovskite	?	

INTERFERENCES:

LINE	N	I	LiF (200)	KeV
Tm Lγ1	2	5	2.6306	9.42
Ho L1-O4,5	2	.01	2.6416	9.39
Er Lγ2	2	1	2.6420	9.38
Ho Lγ4	2	.1	2.6450	9.37
Pt Lα2	2	10	2.6486	9.36
Hf Lβ2	2	20	2.6528	9.35
Hf Lβ15	2	1	2.6557	9.34
La Lα1	1	100	2.6657	4.65
Cs Lβ4	1	5	2.6666	4.65
Lu Lβ9	2	.01	2.6716	9.28
La Lα2	1	10	2.6753	4.63
Nd L1	1	2	2.6760	4.63
Er Lγ6	2	.01	2.6794	9.25
Lu Lβ5	2	.1	2.6837	9.24
Cs Lβ1	1	50	2.6837	4.62
Lu Lβ10	2	.01	2.6860	9.23
Lu L3-O2,3	2	.01	2.6905	9.22

NOTES: Chief interferences come from 1st order $CsL\beta4$ and Nd_{L1} x-ray lines. Due to the similar energies of these lines with $La_{L\alpha}$, a PHA is of no use as an energy discriminator. All 2nd order lines can be dealt with using a PHA.

CERIUM

TABLE 58

ELEMENT: Ce

ANALYTICAL LINE: $L_\alpha 1$

CRYSTAL: LiF

SPECTROMETER SETTING: 2.5615

BACKGROUND SETTING:

ELEMENTAL SCANS:

MINERAL	WT % OXIDE	BACKGROUND SETTING
Glass REE 3	4.00	±0.027
perovskite	?	

INTERFERENCES:

LINE		N	I	LiF (200)	KeV
	Tm LY3	2	1	2.5356	9.78
	Tm Lγ2	2	1	2.5484	9.73
	Er Lγ4	2	.1	2.5504	9.72
	Ba Lβ4	1	5	2.5553	4.85
Ce	Lα1	1	100	2.5615	4.84
	Po L1	2	3	2.5658	9.66
	Ba Lβ1	1	50	2.5682	4.83
Ce	Lα2	1	10	2.5706	4.82
	Hf Lβ9	2	.01	2.5805	9.61
	Tm Lγ6	2	.01	2.5810	9.61
	Zn Kβ1,3	2	20	2.5905	9.57

NOTES: Chief interference is from Ba Lβ1 and Lβ4. Similar X-ray energies prevent energy discrimination with a PHA. All other lines can be discriminated against using the PHA.

PRASEODYMIUM

TABLE 59

ELEMENT: Pr

ANALYTICAL LINE: $L_\alpha 1$

CRYSTAL: LiF

SPECTROMETER SETTING: 2.4630

BACKGROUND SETTING:

ELEMENTAL SCANS:

MINERAL	WT % OXIDE	BACKGROUND SETTING
Glass REE 3	4.45	±0.027

INTERFERENCES:

	LINE	$\underline{N}$	$\underline{I}$	LiF (200)	KeV
	Hf $L_\gamma 5$	2	.1	2.4307	10.20
	Th M_1-O_3	1	.01	2.4420	5.08
	U M_2-O_4	1	.01	2.4430	5.07
	Lu $L_\gamma 1$	2	5	2.4446	10.14
	Yb $L_\gamma 3$	2	1	2.4446	10.14
	La $L_\beta 4$	1	5	2.4493	5.06
	Tm $L_1 O_{4,5}$	2	.01	2.4526	10.11
	Yb $L_\gamma 2$	2	1	2.4576	10.09
	Tm $L_\gamma 4$	2	.1	2.4588	10.08
	La $L_\beta 1$	1	50	2.4589	5.04
Pr	$L_\alpha 1$	1	100	2.4630	5.03
Pr	$L_\alpha 2$	1	10	2.4729	5.01
	Sm $L1$	1	2	2.4823	4.99

Ba Lβ6	1	.1	2.4826	4.99
Yb Lγ6	2	.01	2.4854	9.98
Pt Ln	2	1	2.4858	9.97
Yb L_2-$0_{2,3}$	2	.01	2.4906	9.95

NOTES: Interferences which occur and which the analyst is helpless against
are: Th$_{M1}$-0_3, U$_{M2}$-0_4, La $_{Lβ4}$, La$_{Lβ1}$, Sm$_l$, and Ba$_{Lβ6}$. La would be
the most likely problem. All other lines can be discriminated
aginst with a PHA.

NEODYMIUM

TABLE 60

ELEMENT: Nd

ANALYTICAL LINE: Lα1

CRYSTAL: LiF

SPECTROMETER SETTING: 2.3704

BACKGROUND SETTING:

ELEMENTAL SCANS:

MINERAL	WT % OXIDE	BACKGROUND SETTING
Glass REE 2	4.26	±0.030
Perovskite		

INTERFERENCES:

	LINE	N	I	LiF (200)	KeV
	Cs Lγ1	1	5	2.3480	5.28
	Sr Kβ1	3	16	2.3488	15.83
	Ce Lβ4	1	5	2.3497	5.28
	Pb Lα1	2	100	2.3500	10.55
	Ce Lβ1	1	50	2.3561	5.26
	Zr Kα1,2	3	150	2.3620	15.74
	Po Lγ1	3	10	2.3624	15.74
Nd	Lα1	1	100	2.3704	5.23
	La Lβ6	1	.1	2.3790	5.21
	Ba Lβ7	1	.1	2.3806	15.62
Nd	Lα2	1	10	2.3807	5.21
	Ba Lβ10	1	.01	2.3869	5.18
	Eu L1	1	2	2.3948	5.18
	Ba Lβ2,15	1	20	2.4044	5.16

NOTES: Intense X-ray lines from elements such as Zr, Pb are more energetic than Nd Lα and can be discriminated against with a PHA. Elements such as Ce, La and Ba, if present in the matrix, cannot be discriminated against and interfere with the measurement.

SAMARIUM

TABLE 62

ELEMENT: Sm

ANALYTICAL LINE: Lα1

CRYSTAL: LiF

SPECTROMETER SETTING: 2.1998

BACKGROUND SETTING:

ELEMENTAL SCANS:

MINERAL	WT % OXIDE	BACKGROUND SETTING
Glass REE 2	4.26	-0.017

INTERFERENCES:

	LINE	N	I	LiF (200)	KeV
	Nd Lβ1	1	50	2.1669	5.72
	Cs Lγ4	1	.1	2.1741	5.70
	Ce Lβ7	1	.1	2.1806	5.69
	Ce Lβ9	1	.01	2.1885	5.66
	Pı Lβ6	1	.1	2.1906	5.66
	Ce Lβ10	1	.01	2.1958	5.65
Sm	Lα1	1	100	2.1998	5.64
	Pt Lβ2	2	20	2.2040	11.25
	La Lγ5	1	.1	2.2056	5.62
	Ce Lβ2,15	1	20	2.2087	5.61
Sm	Lα2	1	10	2.2106	5.61
	Pr Lβ3	1	6	2.2172	5.59
Sm	Ln	1	1	2.2182	5.59
	Po Lα1	2	100	2.2277	11.13

NOTES: Ce, Cs, Pr, or La in the sample matrix can present a problem. Ce is
the chief problem, but the continuum is loaded with other lines of
similar energy. PHA is only useful for Pt and Po.

EUROPIUM

TABLE 63

ELEMENT: Eu

ANALYTICAL LINE: Lα1

CRYSTAL: LiF

SPECTROMETER SETTING: 2.1209

BACKGROUND SETTING:

ELEMENTAL SCANS:

MINERAL	WT % OXIDE	BACKGROUND SETTING
Glass REE 1	4.21	±0.030

INTERFERENCES:

LINE	N	I	LiF (200)	KeV
Pr Lβ7	1	.1	2.0919	5.93
Pr Lβ9	1	.1	2.1000	5.90
Mn Kα1,2	1	150	2.1031	5.89
Nd Lβ6	1	.1	2.1039	5.89
Pr Lβ10	1	.01	2.1071	5.88
Ce Lγ5	1	.1	2.1103	5.87
Pr Lβ2.15	1	20	2.1194	5.85
Eu Lα1	1	100	2.1209	5.85
Nd Lβ3	1	6	2.1268	5.83
Eu LN	1	1	2.1315	5.82
Eu Lα2	1	10	2.1315	5.82
Ba Lγ3	1	1	2.1342	5.81
Ba Lγ2	1	1	2.1387	5.80
La Lγ1	1	5	2.1418	5.79

NOTES: All of the x-ray lines occuring near Eu are of similar energies and
        therefore impossible to discriminate against with a PHA. Aside from
        La, Pr, Nd and Ba occuring very near the peak, $Mn_{Kα1,2}$ is apt to be
        more of a problem, and depending on the Mn concentration level, the
        Eu might be sitting in the Mn peak tail.

GADOLINIUM

TABLE 64

ELEMENT: Gd

ANALYTICAL LINE: Lα1

CRYSTAL: LiF

SPECTROMETER SETTING: 2.0468

BACKGROUND SETTING:

ELEMENTAL SCANS:

MINERAL	WT % OXIDE	BACKGROUND SETTING
Glass REE 1	4.47	±0.030

INTERFERENCES:

	LINE	N	I	LiF (200)	KeV
	Nd Lβ9	1	.01	2.0165	6.15
	Pr Lγ5	1	.1	2.0205	6.14
	Nd Lβ10	1	.01	2.0237	6.13
	Ce Lγ8	1	.1	2.0237	6.13
	Nd Lβ2,15	1	20	2.0360	6.09
	La Lγ3	1	1	2.0410	6.07
	Pm Lβ3	1	6	2.0410	6.07
	La Lγ2	1	1	2.0460	6.06
Gd	Lα1	1	100	2.0468	6.06
	Ce Lγ1	1	5	2.0487	6.05
Gd	LN	1	1	2.0494	6.05
Gd	Lα2	1	10	2.0578	6.02
	Cr Kβ5	1	.03	2.0709	5.99
	Ba Lγ4	1	.1	2.0756	5.97

NOTES: Chief interferences are Nd, Pm and Ce. A PHA will not help since all x-ray lines are of similar energy.

TERBIUM

TABLE 65

ELEMENT: Tb

ANALYTICAL LINE: Lα1

CRYSTAL: LiF

SPECTROMETER SETTING: 1.9765

BACKGROUND SETTING:

ELEMENTAL SCANS:

MINERAL	WT % OXIDE	BACKGROUND SETTING
Glass REE 1	4.27	±0.026

INTERFERENCES:

LINE	N	I	LiF (200)	KeV
Sm Lβ6	1	.1	1.9464	6.37
Ce Lγ3	1	1	1.9553	6.34
Pm Lβ2,15	1	20	1.9559	6.34
Ce Lγ2	1	1	1.9602	6.32
Pr Lγ1	1	5	1.9611	6.32
Sm Lβ3	1	6	1.9624	6.32
Tb LN	1	1	1.9730	6.28
Tb Lα1	1	100	1.9765	6.27
La Lγ4	1	.1	1.9830	6.25
Tb Lα2	1	10	1.9875	6.24
Sm Lβ1	1	50	1.9981	6.20
Sm Lβ4	1	5	2.0010	6.20

NOTES: Chief interferences for Tb measurement are Sm, Pr, and Pm. As with
         other REE, interfering x-ray lines are of sufficiently similar
         energy that a PHA is of no help.

DYSPROSIUM

TABLE 66

ELEMENT: Dy

ANALYTICAL LINE: Lα1

CRYSTAL: LiF

SPECTROMETER SETTING: 1.9088

BACKGROUND SETTING:

ELEMENTAL SCANS:

MINERAL	WT % OXIDE	BACKGROUND SETTING
Glass REE 4	4.36	±0.030

INTERFERENCES:

	LINE	N	I	LiF (200)	KeV
	Nd Lγ1	1	5	1.8779	6.60
	Pr Lγ2	1	1	1.8791	6.60
	Sm Lβ2,15	1	20	1.8822	6.59
	Eu Lβ3	1	6	1.8867	6.57
	Yb L1	1	2	1.8942	6.54
Dy	LN	1	1	1.8974	6.53
	Ce Lγ4	1	.1	1.8991	6.53
Dy	Lα1	1	100	1.9088	6.49
	MnKβ1,3	1	20	1.9102	6.49
	Th Lα1	2	100	1.9120	12.97
Dy	Lα2	1	10	1.9199	6.46
	Eu Lβ1	1	50	1.9203	6.46
	Eu Lβ4	1	5	1.9255	6.44

Nd Lγ5	1	.1	1.9355	6.41
Th Lα2	2	10	1.9358	12.81
Pr Lγ8	1	.1	1.9362	6.40
Fe Kα1,2	1	150	1.93/4	6.40

NOTES: Dy in a mafic mineral will be almost impossible to analyze due to the large Fe and Mn concentrations. In fact, the Dy (peak) is apt to be sitting in the Fe tail and MnKβ1 is right on top of the Dy peak. All X-ray lines, with the exception of Th, are of similar energy and impossible to discriminate against with a PHA. These problems aside, Eu and Sm will also cause interference. Very difficult to analyze.

HOLMIUM

TABLE 67

ELEMENT: Ho

ANALYTICAL LINE: Lα1

CRYSTAL: LiF

SPECTROMETER SETTING: 1.8450

BACKGROUND SETTING:

ELEMENTAL SCANS:

MINERAL	WT % OXIDE	BACKGROUND SETTING
Glass REE 4	4.41	±0.030

INTERFERENCES:

LINE	N	I	LiF (200)	KeV
Eu Lβ2,15	1	20	1.8118	6.84
Gd Lβ3	1	6	1.8150	6.83
Pr Lγ4	1	.1	1.8193	6.81
U Lα1	2	100	1.8213	13.61
Ho LN	1	1	1.8264	6.79
Yb Lt	1	.01	1.8309	6.77
Lu Ll	1	2	1.8360	6.75
Ho Lα1	1	100	1.8450	6.72
U Lα2	2	10	1.8451	13.44
Gd Lβ1	1	50	1.8468	6.71
Sm Lβ5	1	.1	1.8470	6.71
Rb Kα1,2	2	150	1.8539	13.37
Gd Lβ4	1	5	1.8540	6.69
Nd Lγ8	1	.1	1.8552	6.68

Ho	Lα2	1	10	1.8561	6.68
	Sm Lβ7	1	.1	1.8563	6.68
	Sm Lβ9	1	.01	1.8617	6.66
	Sm Lβ10	1	.01	1.8699	6.63
	Eu Lβ6	1	.1	1.8737	6.62
	Pr Lγ3	1	1	1.8740	6.62

NOTES: Chief Ho interferences are Gd, Rb, Lu, U, and Eu. U and Rb are the only X-ray lines which can be discriminated against using a PHA.

ERBIUM

TABLE 68

ELEMENT: Er

ANALYTICAL LINE: Lα1

CRYSTAL: LiF

SPECTROMETER SETTING: 1.7843

BACKGROUND SETTING:

ELEMENTAL SCANS:

MINERAL	WT % OXIDE	BACKGROUND SETTING
Glass REE 4	4.36	±0.030

INTERFERENCES:

LINE	$\underline{N}$	$\underline{I}$	LiF (200)	KeV
Sr Kα1,2	2	150	1.7533	14.14
Fe Kβ1,3	1	20	1.7566	7.06
Lu Lt	1	.01	1.7760	6.98
Tb Lβ1	1	50	1.7768	6.98
Eu Lβ5	1	.1	1.7772	6.98
Sm Lγ5	1	.1	1.7793	6.97
Er Lα1	1	100	1.7843	6.95
Eu Lβ7	1	.1	1.7851	6.94
Tb Lβ4	1	5	1.7864	6.94
Co Kα1,2	1	150	1.7903	6.92
Eu Lβ9	1	.01	1.7916	6.92
Er Lα2	1	10	1.7955	6.90

Nd Lγ3	1	1	1.7964	6.90
Pm Lγ1	1	5	1.7989	6.89
Eu Lβ10	1	.01	1.7993	6.89
Nd Lγ2	1	1	1.8013	6.88
Gd Lβ6	1	.1	1.8054	6.87
Eu Lβ2,15	1	20	1.8118	6.84

NOTES: Major sources of interference are $Co_{K\alpha1,2}$; $Fe_{K\beta1,3}$; $Tb_{L\beta4}$ and $Tb_{L\beta1}$. All lines except Sr are of similar energy and therefore a PHA cannot discriminate against them.

THULIUM

TABLE 69

ELEMENT: Tm

ANALYTICAL LINE: Lα1

CRYSTAL: LiF

SPECTROMETER SETTING: 1.7268

BACKGROUND SETTING:

ELEMENTAL SCANS:

MINERAL	WT % OXIDE	BACKGROUND SETTING
Glass REE 1	4.36	-0.043

INTERFERENCES:

	LINE	N	I	LiF (200)	KeV
Tm	Ln	1	1	1.6963	7.31
	Sm Lγ6	1	.01	1.6967	7.31
	Sm Lγ8	1	.1	1.7063	7.27
	Eu Lγ5	1	.1	1.7085	7.26
	Dy Lβ1	1	50	1.7106	7.25
	Gd Lβ5	1	.1	1.7130	7.24
	Gd Lβ7	1	.1	1.7203	7.21
	Dy Lβ4	1	5	1.7210	7.20
	Gd Lβ9	1	.01	1.7240	7.19
Tm	Lα1	1	100	1.7268	7.18
	Sm Lγ1	1	5	1.7272	7.18
	Gd Lβ10	1	.01	1.7315	7.16
Tm	Lα2	1	10	1.7381	7.13
	Fe Kβ5	1	.03	1.7442	7.11

Nd Lγ4	1	.1	1.7445	7.11
Gd Lβ2,15	1	20	1.7455	7.10
Tb Lβ3	1	6	1.7472	7.10
Sr Kα1,2	2	150	1.7533	14.14
Er Ln	1	1	1.7566	7.06
Fe Kβ1,3	1	20	1.7566	7.06

NOTES: Dy, Sm, Fe, Gd, and Sr can interfere with the Tm determination.
Of these, only Sr can be excluded with a PHA.

YTTERBIUM

TABLE 70

ELEMENT: Yb

ANALYTICAL LINE: Lα1

CRYSTAL: LiF

SPECTROMETER SETTING: 1.6719

BACKGROUND SETTING:

ELEMENTAL SCANS:

MINERAL	WT % OXIDE	BACKGROUND SETTING
Glass REE 2	4.26	±0.026

INTERFERENCES:

LINE	N	I	LiF (200)	KeV
Ho Lβ1	1	50	1.6475	7.52
Tb Lβ5	1	.1	1.6510	7.51
Sm Lγ3	1	1	1.6560	7.49
Eu Lγ1	1	5	1.6574	7.48
Tb Lβ7	1	.1	1.6585	7.48
Ni Kα1,2	1	150	1.6592	7.47
Ho Lβ4	1	5	1.6595	7.47
Sm Lγ2	1	1	1.6604	7.47
Y Kα1,2	2	150	1.6605	14.93
Tb Lβ10	1	.01	1.6673	7.44
Yb Lα1	1	100	1.6719	7.41
Dy Lβ6	1	.1	1.6821	7.37
Dy Lβ3	1	6	1.6822	7.37
Yb Lα2	1	10	1.6829	7.37
Tb Lβ2,15	1	20	1.6830	7.37
Tm Ln	1	1	1.6963	7.31
Sm Lγ6	1	.01	1.6967	7.31

NOTES: Of the interfering lines Ni Kα1,2; Y Kα1,2; DyLβ3 and Tb$_{Lβ2,15}$ a
PHA will only be useful to discriminate against Y. All other X-ray
lines are of similar energy and impossible to exclude.

LUTETIUM

TABLE 71

ELEMENT: Lu

ANALYTICAL LINE: Lα1

CRYSTAL: LiF

SPECTROMETER SETTING: 1.6195
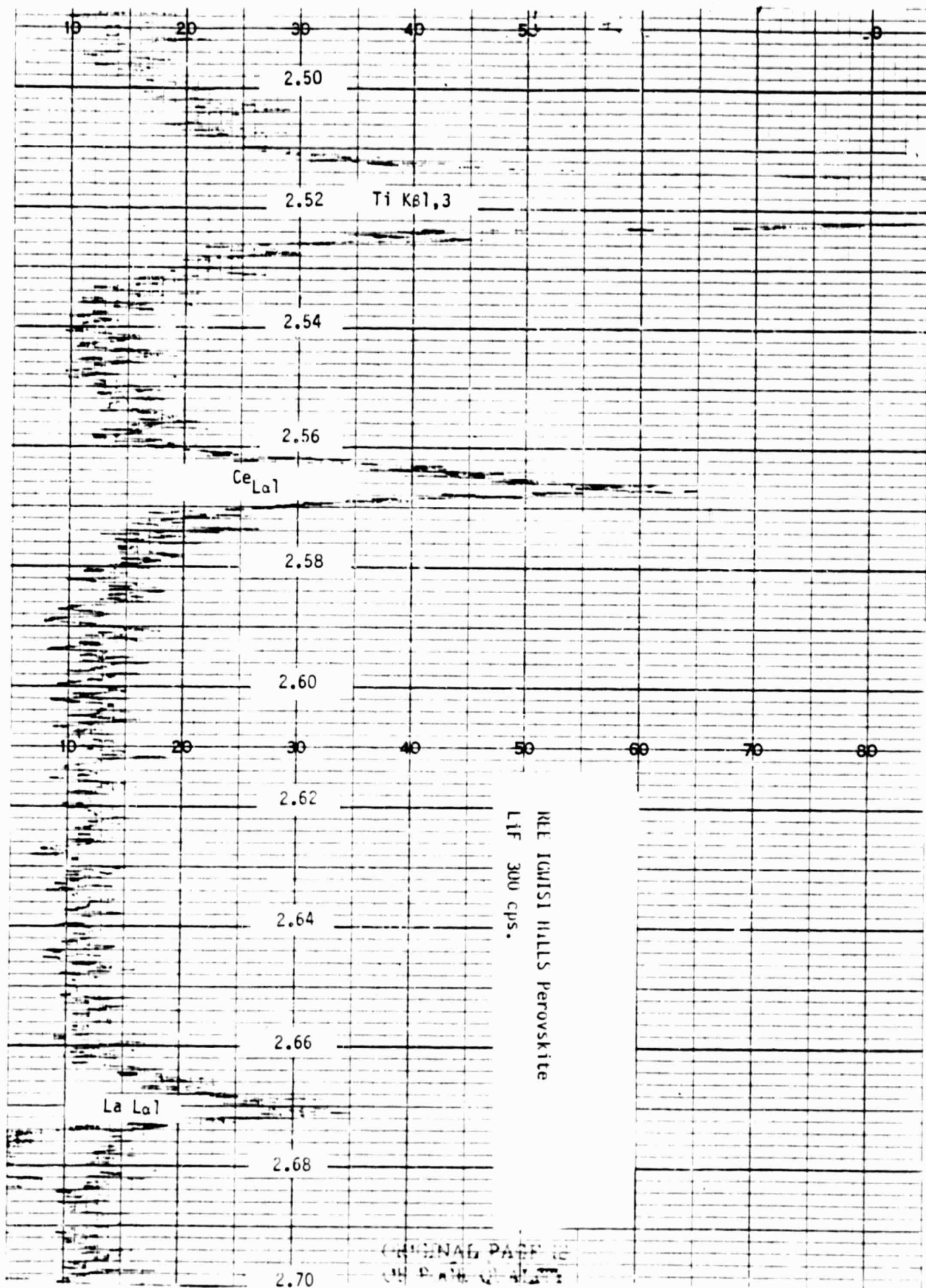
BACKGROUND SETTING:

ELEMENTAL SCANS:

MINERAL	WT % OXIDE	BACKGROUND SETTING
Glass REE 2	4.26	±0.026

INTERFERENCES:

LINE	N	I	LiF (200)	KeV
Dy Lβ5	1	.1	1.5884	7.80
Yb L$_2$-N$_2$	1	.01	1.5884	7.80
Eu Lγ3	1	1	1.5903	7.80
Gd Lγ1	1	5	1.5924	7.78
Eu Lγ2	1	1	1.5961	7.77
Dy Lβ9	1	.01	1.5997	7.75
Er Lβ4	1	5	1.6007	7.74
Dy Lβ7	1	.1	1.6045	7.73
Sm Lγ4	1	.1	1.6073	7.71
Dy Lβ10	1	.01	1.6074	7.71
Co Kβ5	1	.03	1.6089	7.71
Lu Lα1	1	100	1.6195	7.65
Co Kβ1,3	1	20	1.6208	7.65
Dy Lβ2,15	1	20	1.6237	7.63
Ho Lβ6	1	.1	1.6237	7.63

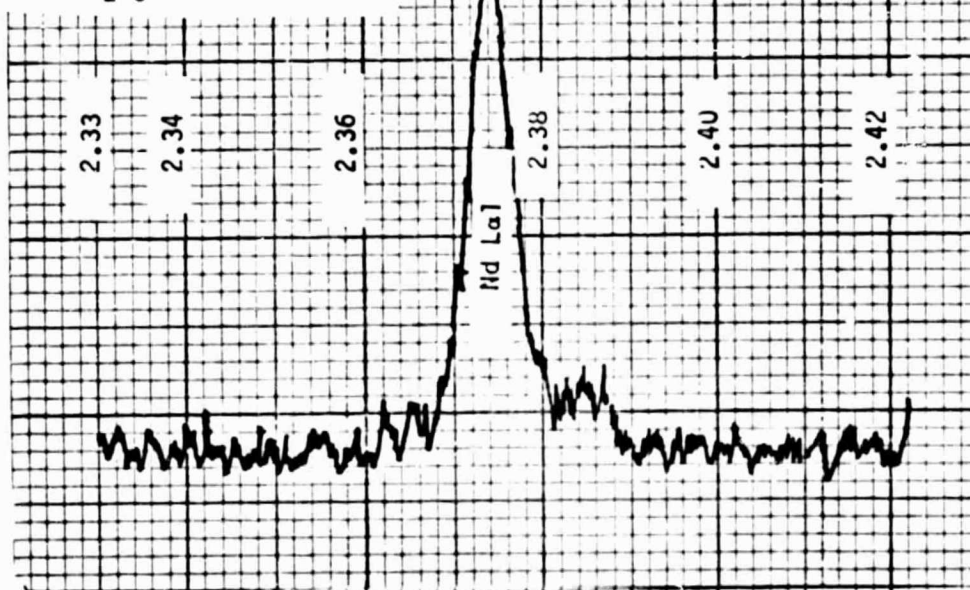|					
	Eu Lγ6	1	.01	1.6282	7.61
Lu	Lα2	1	10	1.6303	7.60
	Eu Lγ8	1	.1	1.6346	7.58
	Yb Ln	1	1	1.6356	7.58
	Gd Lγ5	1	.1	1.6412	7.55

NOTES: Chief interferences are from Co, Dy, Er and Gd. A PHA is of no help as an energy discriminator since all the lines are of similar X-ray energy.
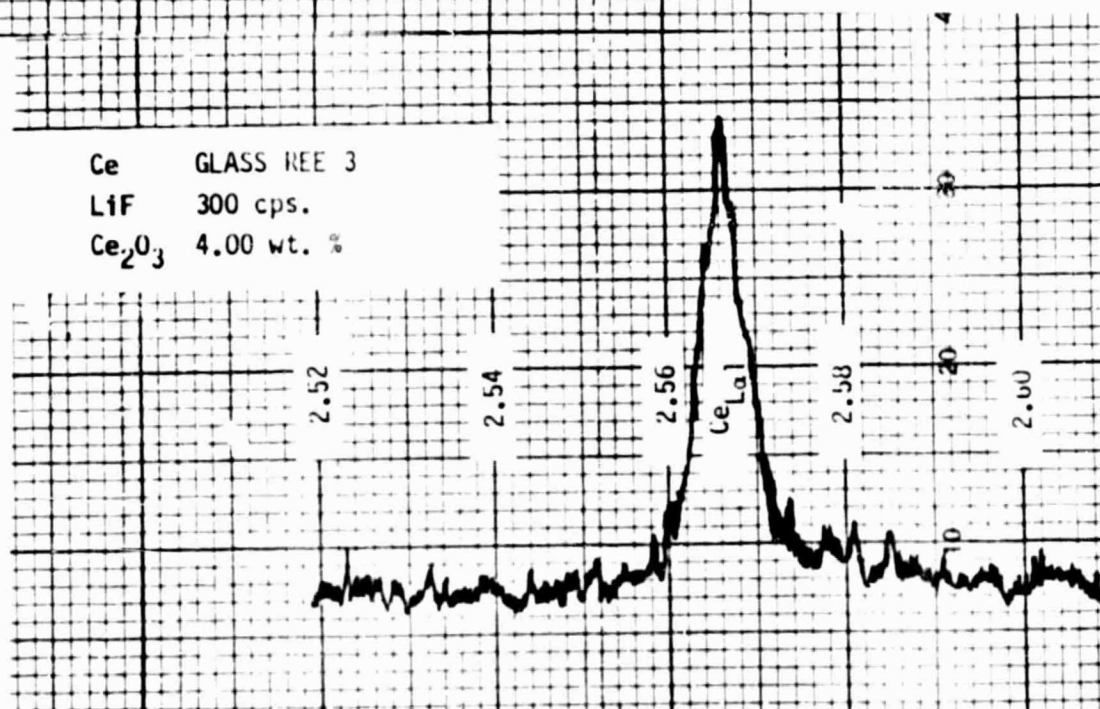
2.50

2.52   Ti Kβ1,3

2.54

2.56

Ce Lα1

2.58

2.60

2.62

2.64

2.66

La Lα1

2.68

2.70

REE IGWISI HALLS Perovskite
LiF 300 cps.

La   GLASS REE 3
LiF   300 cps.
La_2O_3 4.28 wt. %
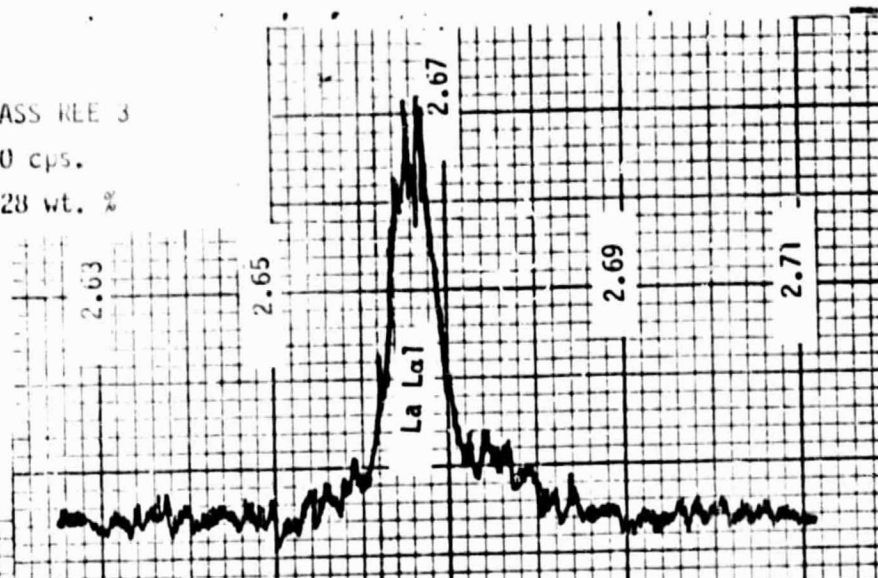
Nd   GLASS REE 2
LiF   300 cps.
Nd_2O_3 4.26 wt. %

Ce   GLASS REE 3
LiF   300 cps.
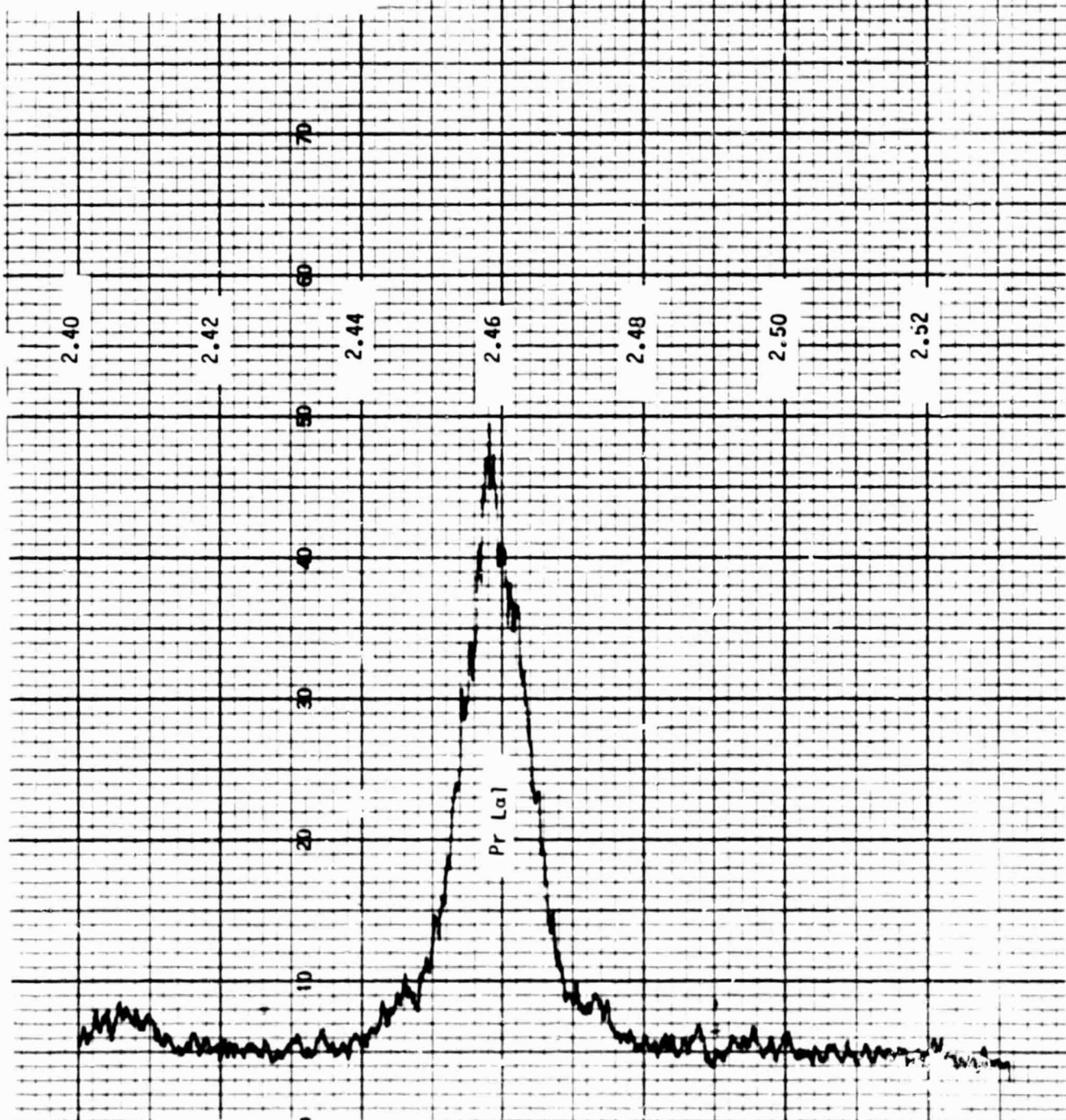Ce_2O_3 4.00 wt. %

REE   IGWISI Hills Perovskite
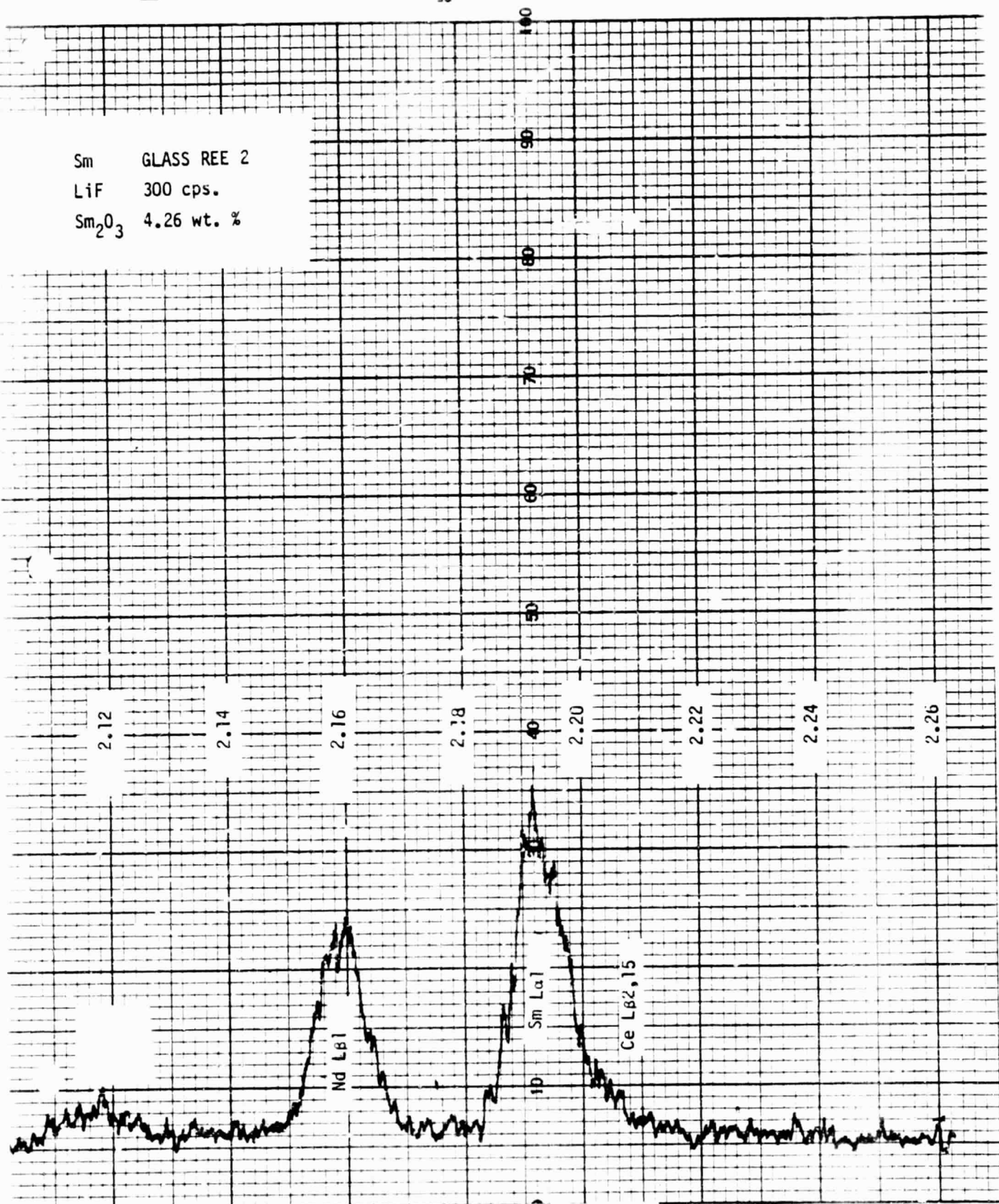LiF   300 cps.

2.32   2.34   2.36   2.38   2.40   2.42

Ce LB1

Nd La1

2.32   2.34   2.36   2.38   2.40

Ce LB1

Nd La1
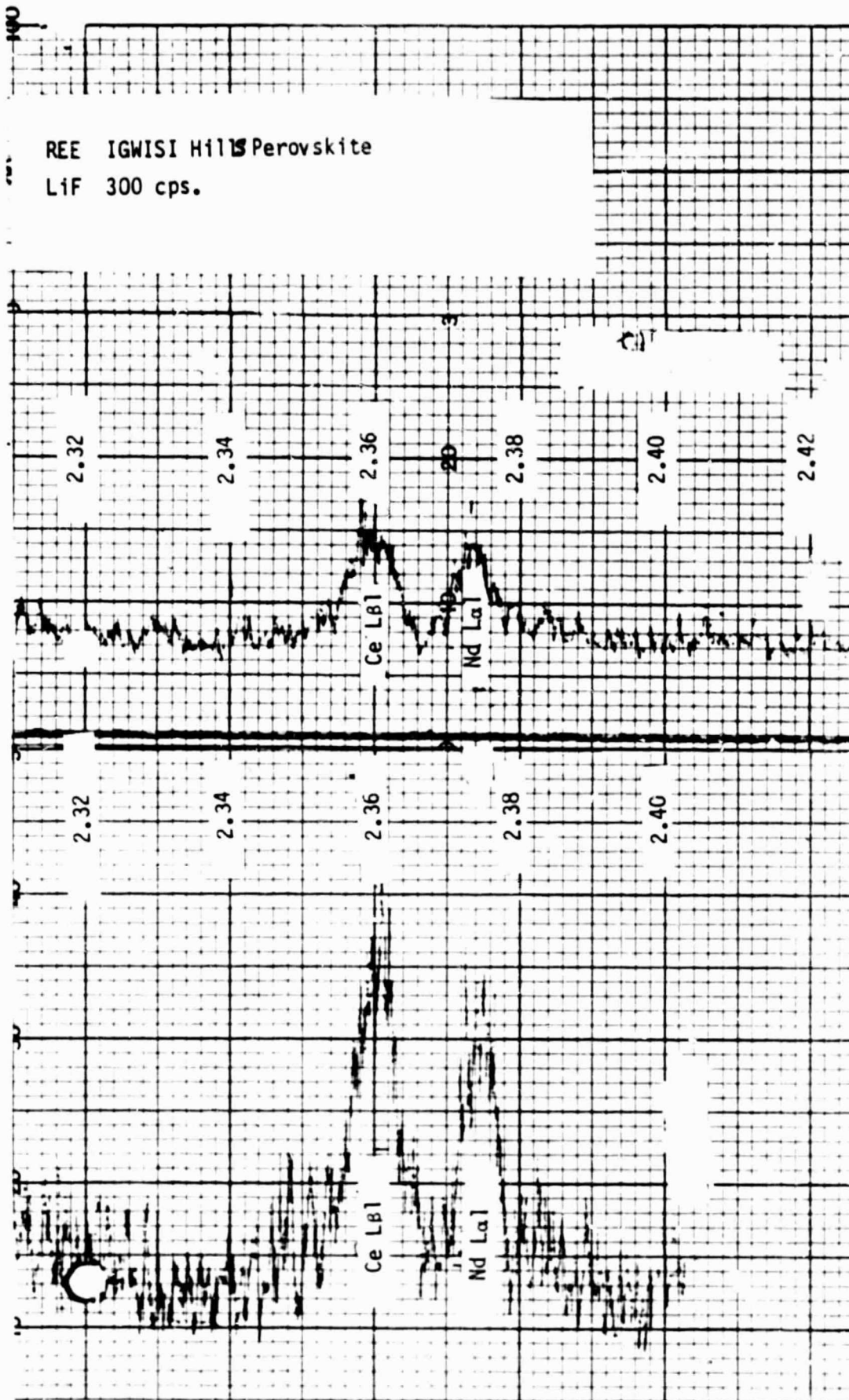
Pr   GLASS REE 3
LiF   300 cps.
Pr$_2$O$_3$ 4.45 wt. %

2.40   2.42   2.44   2.46   2.48   2.50   2.52

Pr Lα1

Sm   GLASS REE 2
LiF   300 cps.
Sm_2O_3 4.26 wt. %

100

90

80

70

60

50

2.12 2.14 2.16 2.18 40 2.20 2.22 2.24 2.26

Nd Lβ1
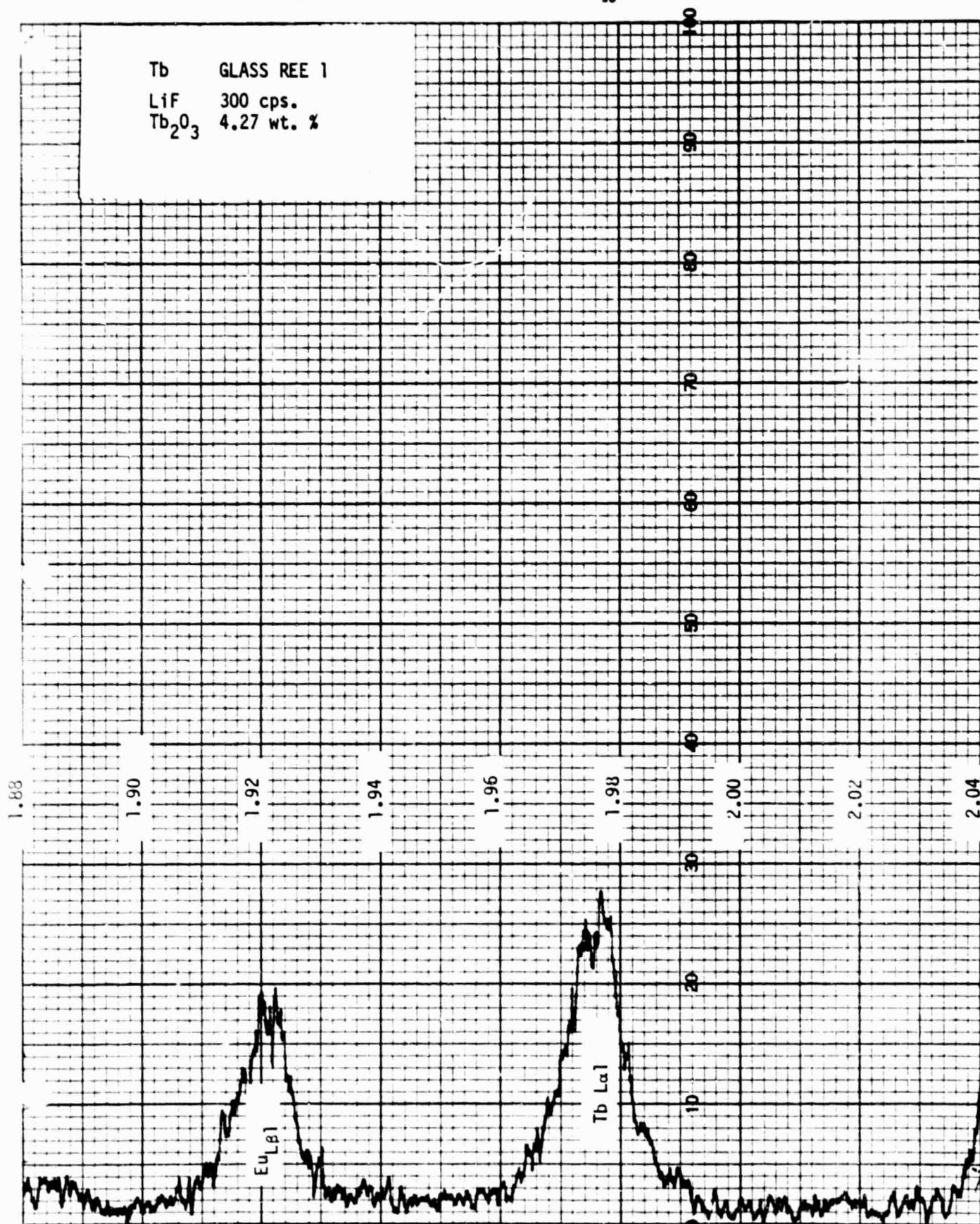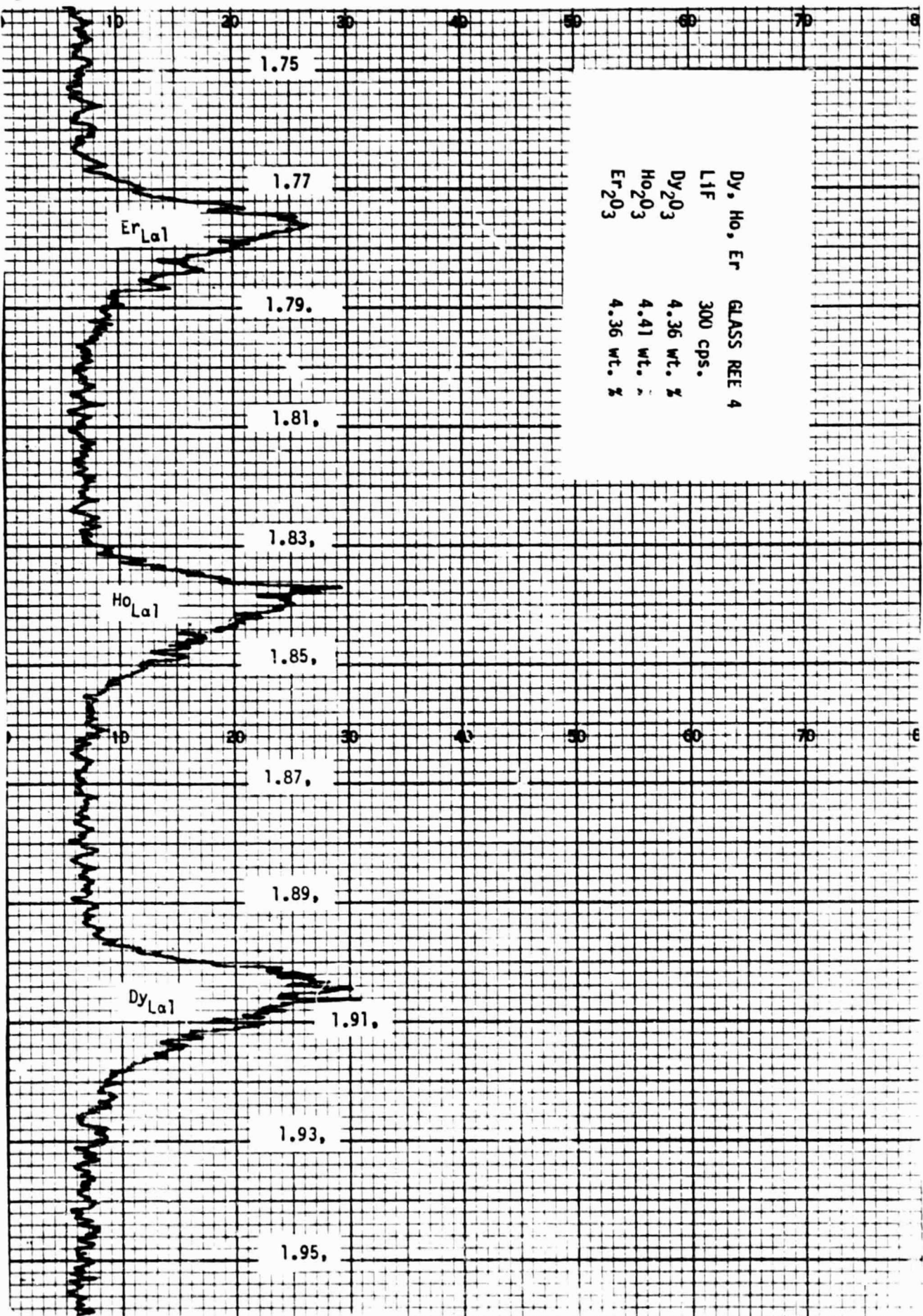
Sm Lα1

Ce Lβ2,15

10

Eu   GLASS REE 1
LiF   300 cps.
EuO   4.21 wt. %

Gd   GLASS REE 1
LiF   300 cps.
Gd$_2$O$_3$ 4.47 wt. %
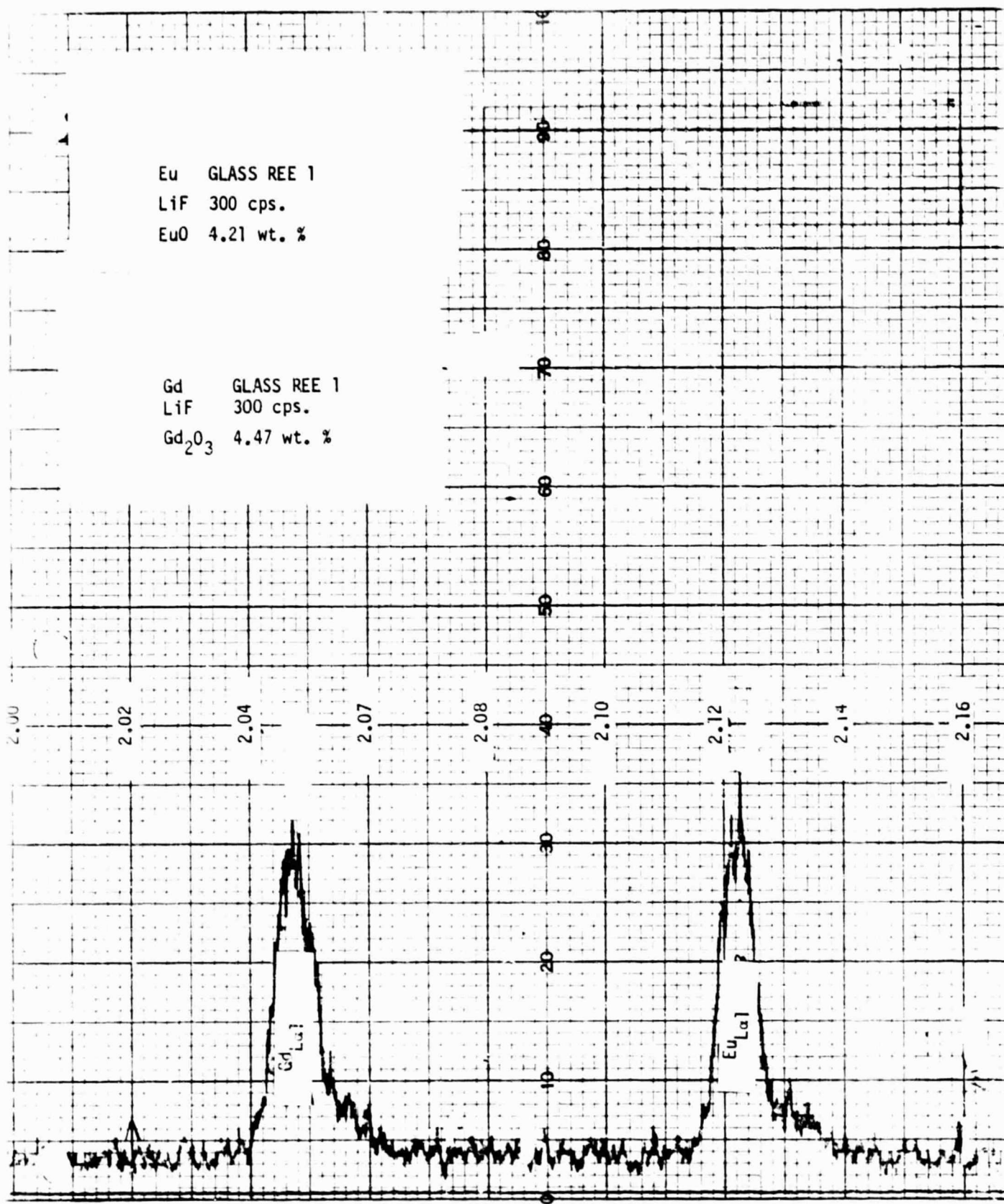
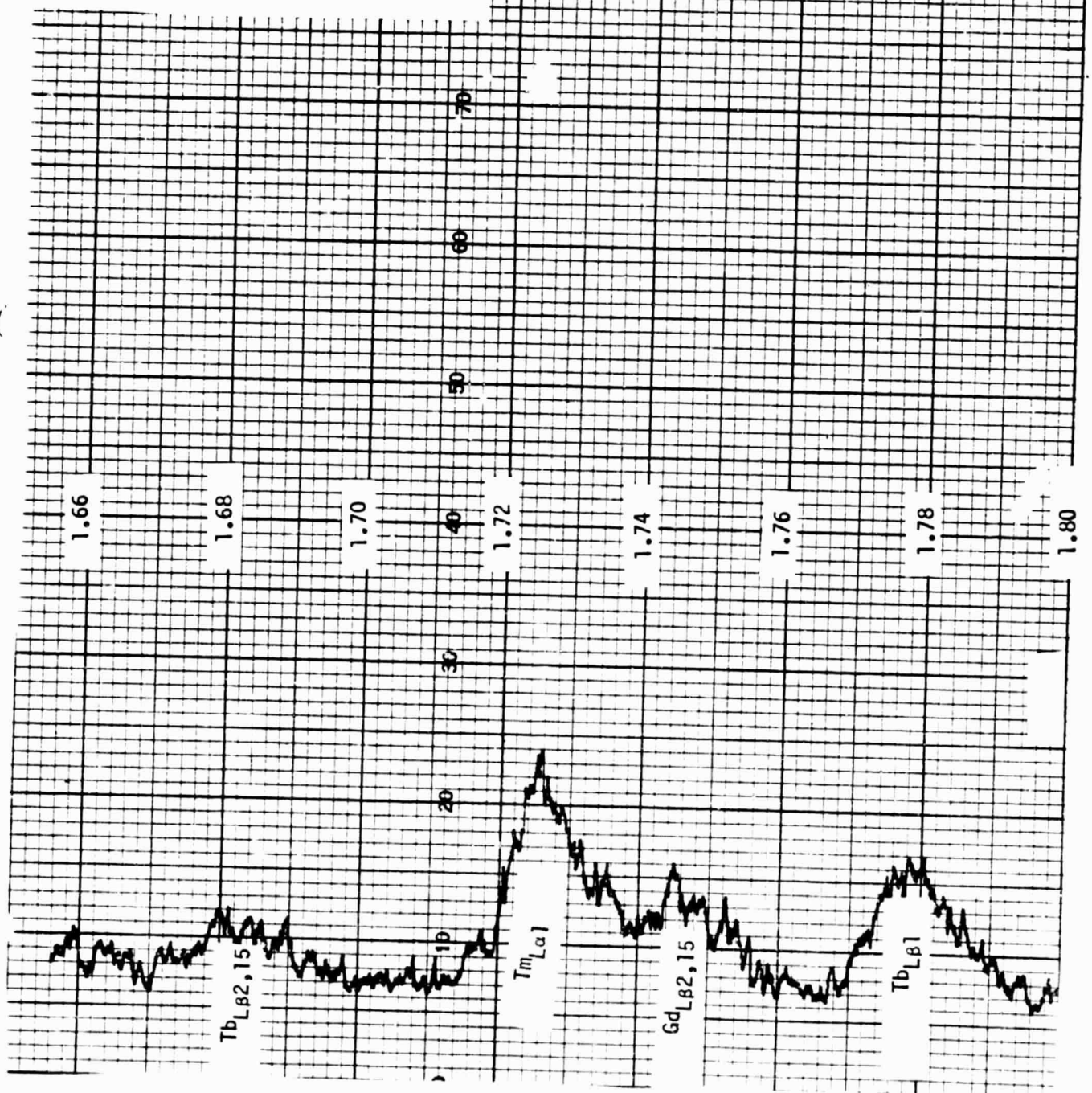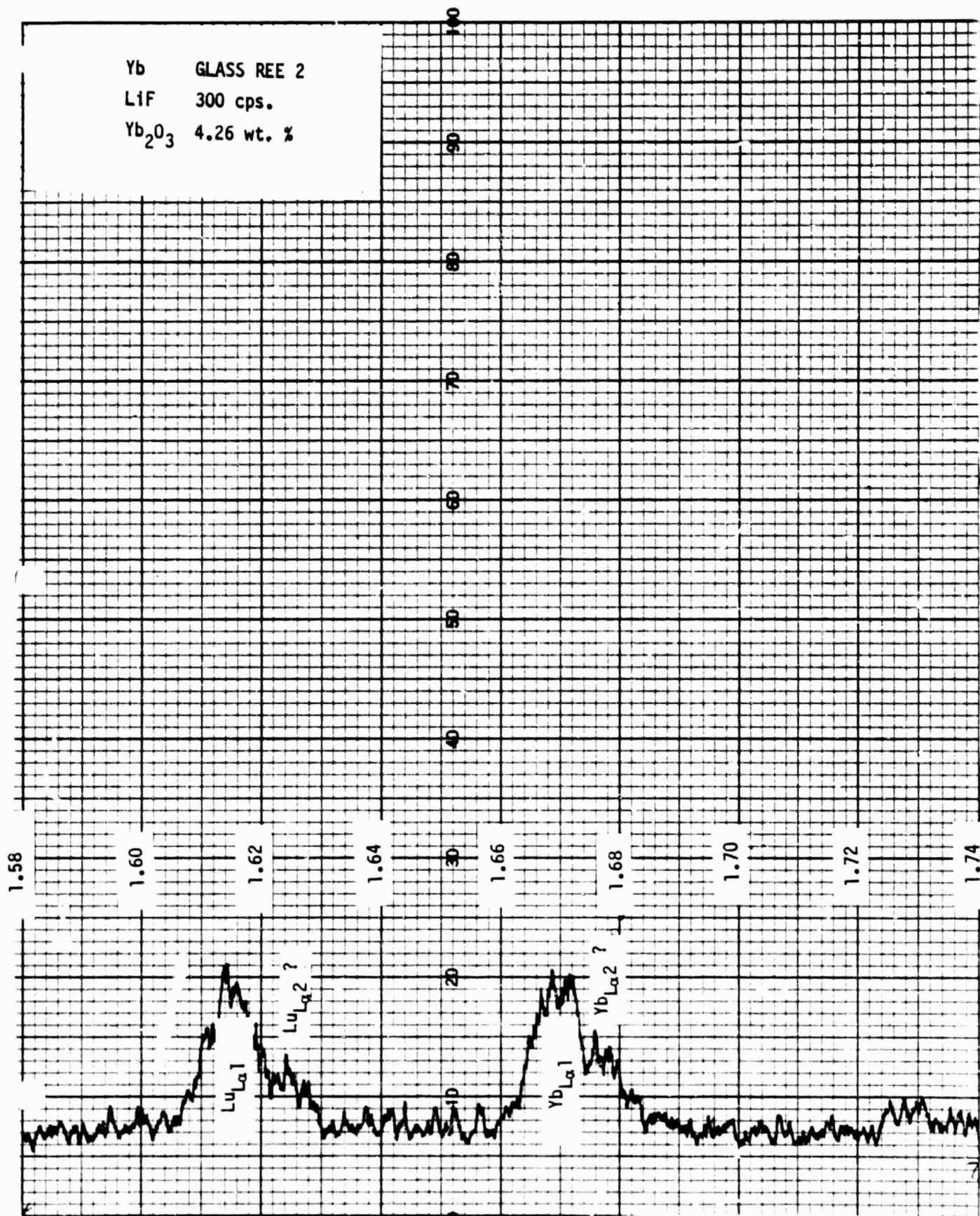Tb   GLASS REE 1
LiF   300 cps.
Tb$_2$O$_3$ 4.27 wt. %

Eu$_{L\beta1}$

Tb Lα1

60

Tm   GLASS REE 1
LiF   300 cps.
Tm_2O_3 4.36 wt. %

Yb   GLASS REE 2
LiF   300 cps.
Yb_2O_3 4.26 wt. %

37
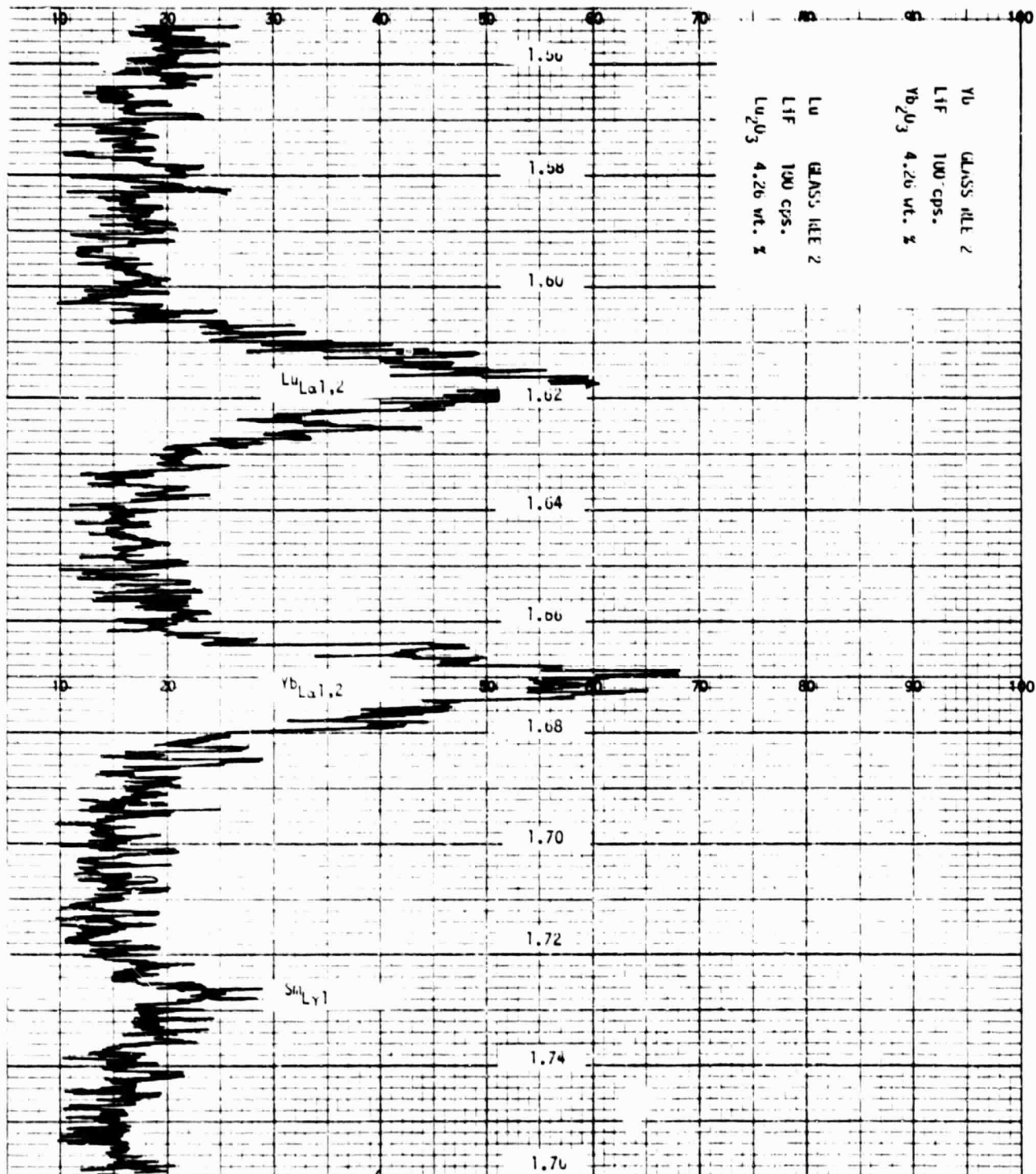
PLATINUM

TABLE 78

ELEMENT: Pt

CRYSTAL: PET

ANALYTICAL LINE: Mα

SPECTROMETER SETTING: 2.7853

BACKGROUND SETTING: ±0.158

ELEMENTAL SCANS:

MINERAL	WT. %	BACKGROUND SETTING
Pt	99.9	±0.158

INTERFERENCES:

LINE		N	I	PET (002)	KeV
Pb	M_3-N_1	1	1	2.6273	2.17
Zr	Lβ6	1	3	2.6301	2.17
Nb	Lα1	1	100	2.6366	2.17
Mn	Kβ1,3	3	20	2.6396	6.49
Nb	Lα2	1	10	2.6401	2.16
P	Kβ1	1	3	2.6733	2.14
Fe	Kα1,2	3	150	2.6771	6.40
Pt	Mβ	1	50	2.6844	2.13
Zr	Lβ1	1	45	2.6881	2.12
Au	Mα1	1	100	2.6899	2.12
Th	Lα1	3	100	2.7312	6.27
Y	Lβ3	1	3	2.7559	2.07
Pt	M_5-O_3	1	.01	2.7576	2.07
Ni	Kβ1,3	4	20	2.7639	8.26
Y	Lβ4	1	3	2.7722	2.06
Pt	Mα1	1	100	2.7853	2.05
Zr	Lα1	1	100	2.7961	2.04
Y	Lβ6	1	3	2.8070	2.03
P	SKα4	1	5	2.8137	2.03

P	SKα3	1	5	2.8173	2.03
Mo	L1	1	3	2.8331	2.02
P	Kα1,2	1	150	2.8364	2.01
Ca	Kβ1,3	2	15	2.8463	4.01
Y	Lβ1	1	45	2.8613	2.00
Cr	Kβ1,3	3	18	2.8809	5.95
Au	M3-N1	1	1	2.8829	1.98
Mn	Kα1,2	3	150	2.9061	5.89
Sr	Lβ3	1	3	2.9328	1.95

NOTES: With a material so widely used in experimental research it is difficult to decide which matrix will not present a problem and which will. The X-ray lines listed above should cover most of the geologic materials normally encountered. A PHA is useful in discriminating against some of the interfering lines — but not all of them. The following is a list of the lines where use of a PHA should be helpful: MnKβ1,3, FeKα1,2, ThLα1, NiKβ1,3, CaKβ1,3, CrKβ1,3, MnKα1,2. For the following x-ray lines a PHA is of little or no help: NbLα1, ZrLβ1, AuMα1, ZrLα1, Pkα1,2, YLβ1.
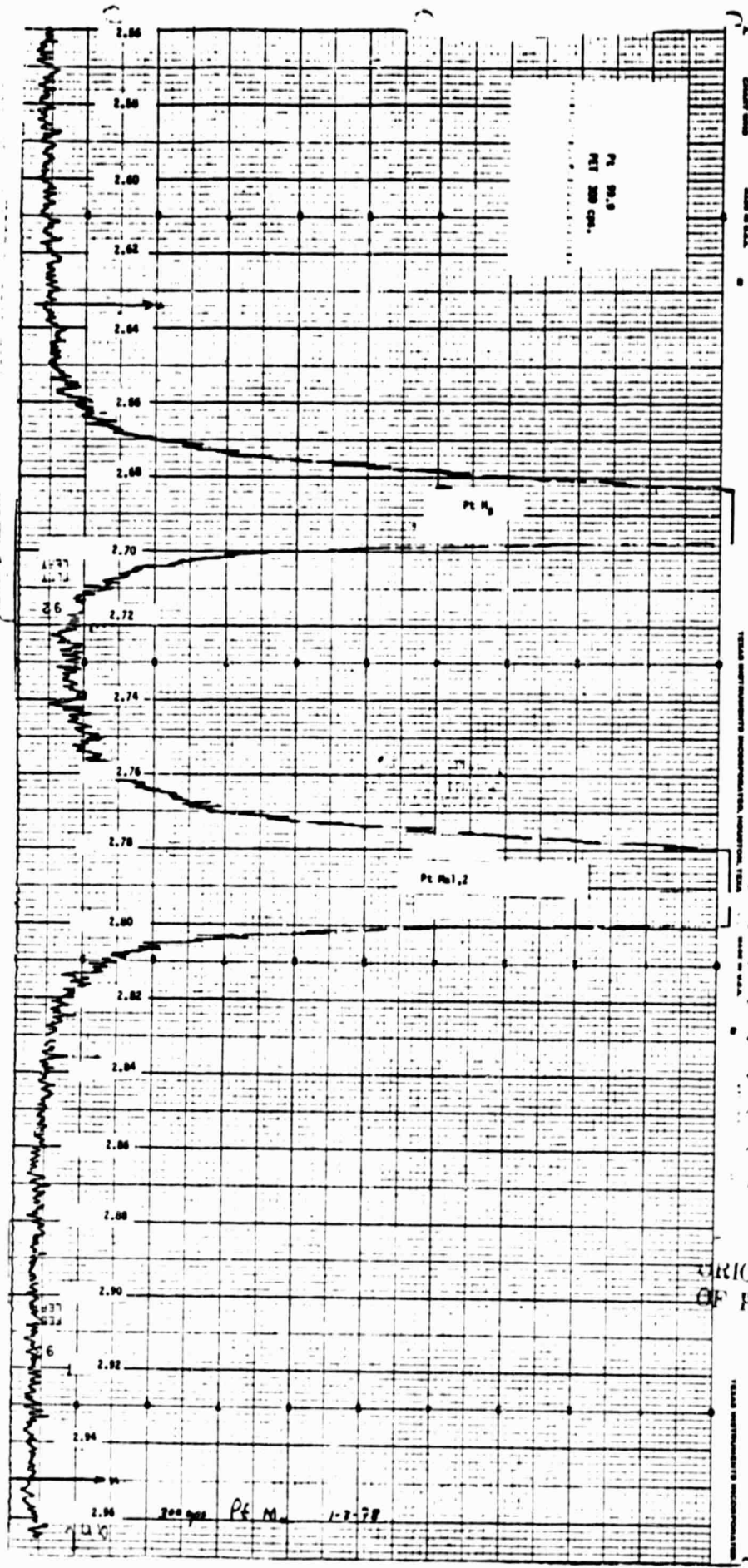
THORIUM

TABLE 90

ELEMENT: Th

ANALYTICAL LINE: Th Mα1,2

CRYSTAL: PET

SPECTROMETER SETTING: 1.91 _ _

BACKGROUND SETTING: ±0.020

ELEMENTAL SCANS:

MINERAL	WT. % OXIDE	BACKGROUND SETTING
GLASS W (PROBE SOCIETY)	0.79	±0.020
Hibonite	0.53	±0.020

INTERFERENCES:

	LINE	$\underline{N}$	$\underline{I}$	PET (002)	KeV
	Gd Lα1	2	100	1.8855	6.06
	Ce Lγ1	2	5	1.8873	6.05
	Bi M3-01	1	.5	1.8908	3.02
	Lu Lβ15	3	20	1.8952	9.04
	Gd Lα2	2	10	1.8957	6.02
	Tl M2-N4	1	1	1.8958	3.01
	Hf Lβ1	3	50	1.8987	9.02
	Rh Lβ2,15	1	25	1.9028	3.00
Th	Mα1	1	100	1.9060	3.00
	Pd Lβ1	1	42	1.9098	2.99
Th	Mα2	1	100	1.9120	2.99
	Ag Lα1	1	100	1.9135	2.98
	Pm Lβ1	2	50	1.9158	5.96
	Ag Lα2	1	10	1.9175	2.98
	Cr Kβ1,3	2	18	1.9206	5.95
	Ru Lγ1	1	1	1.9263	2.96
	Ar Kα1,2	1	150	1.9312	2.96
	Cd Ln	1	1	1.9314	2.96
	Mn Kα1,2	2	150	1.9374	5.89

NOTES: There are several X-ray lines of similar energy as Th Mα and therefore
not excluded with PHA. These include Bi, Tl, Rh, Pd, Ag, Ru, Ar and
Cd. None of these however would typically be found in a Th matrix.
Some REE might present a problem, but usually are of sufficiently
low concentration that higher order reflections will not be seen.

URANIUM

TABLE 92

ELEMENT: U

ANALYTICAL LINE: UMα1,2

CRYSTAL: PET

SPECTROMETER SETTING: 1.80_ __

BACKGROUND SETTING: +0.040

ELEMENTAL SCANS:

MINERAL	WT. % OXIDE	BACKGROUND SETTING
GLASS X (Probe Society)	0.76	±0.040

INTERFERENCES:

	LINE	$\underline{N}$	$\underline{I}$	PET (002)	KeV
	Pd Lγ5	1	.1	1.7605	3.24
	Th Lα1	4	100	1.7613	12.97
	Ag Lβ3	1	11	1.7656	3.24
	Bi M2-N4	1	5	1.7660	3.23
	Dy Lα2	2	10	1.7686	6.46
	Eu Lβ1	2	50	1.7690	6.64
	Ag Lβ4	1	5	1.7826	3.20
	Pb Mi-N3	1	.1	1.7835	3.20
	Fe Kα1,2	2	150	1.7847	6.40
	Ar Kβ1,3	1	15	1.7899	3.19
	Sb L1	1	7	1.7909	3.19
	Bi M1-N2	1	1	1.7927	3.19
	Ru Lγ2,3	1	.5	1.7953	3.18
	Pd Lβ2,15	1	25	1.8004	3.17
U	Mα1	1	100	1.8010	3.17
U	Mα2	1	100	1.8074	3.16
	Pb Lℓ1	4	50	1.8109	12.61
	Bi M3-O4,5	1	1	1.8111	3.15

Ag Lβ1	1	42	1.8124	3.15
Zr Kα1,2	5	150	1.8132	15.74
Th Mβ	1	60	1.8152	3.15
Rh Lγ1	1	10	1.8165	3.14
Tb Lα1	2	100	1.8208	6.27
Cd Lα1	1	100	1.8223	3.13
Pb M2-N4	1	5	1.8277	3.12
In Ln	1	7	1.8347	3.11
Tl M1-N3	1	1	1.8484	3.09
Pd Lβ6	1	1	1.8499	3.09

NOTES: All 1st order x-ray lines occurring within ±Bkg are listed even though (1) background is only counted on the + side of peak and (2) many of the lines are not common to uranium minerals. Higher order lines for elements commonly occurring in uranium minerals are also given, i.e. Pb, Th, Fe, REE. X-ray lines from Th, REE, Fe, Zr and Pb Lβ1 can be exluded with a PHA; the remainder of x-ray lines cannot be discriminated against with a PHA. Most important of these lines is Th Mβ.

Between oxides, carbonates, sulfates, phosphates, arsenates, vanadates, silicates, niobates, tantalates, titanates, and molybdates there are 100 uranium minerals listed in the "Handbook of Geochemistry" Vol. II-1, Springer-Verlag, 1969. Most commonly occurring uranium mineral is uraninite.

U GLASS X
PET 100 cps.
UO_2 0.76 wt. %

$U_{M\alpha 1,2}$

1.78 1.80 1.82 1.84 1.86

Th GLASS W
PET 100 cps.
ThO_2 0.79 wt. %

$Th_{M\beta}$

1.78 1.80 1.82 1.84 1.86 1.88 1.90 1.92 1.94

Hibonite, Madagascar
PET 100 cps.

$Th_{M\beta}$

$Th_{M\alpha 1,2}$
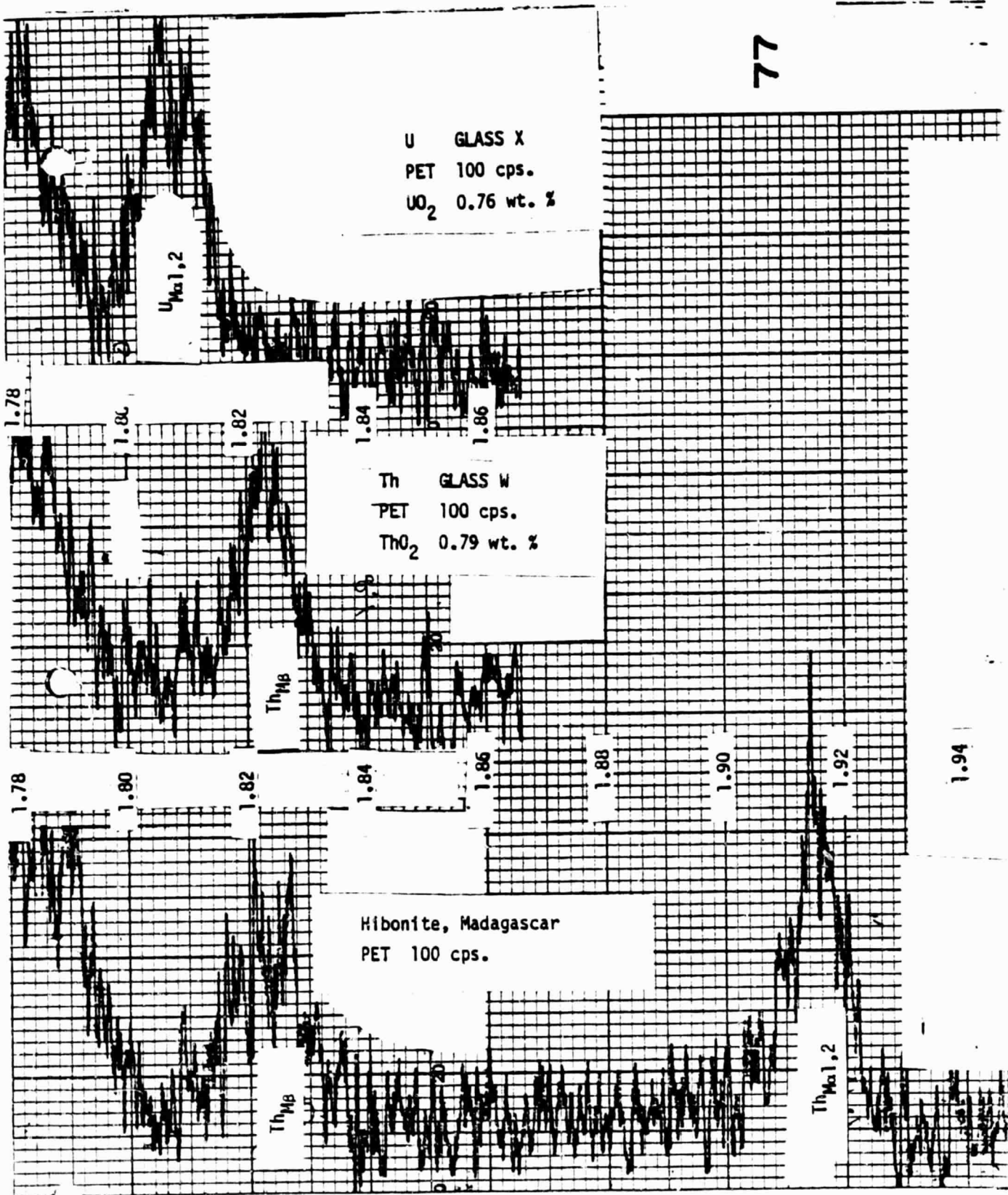
X-RAY OVERLAP AMONG TRANSITION ELEMENTS

TABLE 001

X-RAY OVERLAP AMONG TRANSITION ELEMENTS

ANALYTICAL LINE	INTERFERENCE	(LiF) $\Delta\lambda$	ΔKeV	(PROBLEM)
Ti Kα1,2	Sc Kβ	0.0299	0.05	
V Kα1,2	Ti Kβ	0.0091	0.02	(V in ilmenite)
Cr Kα1,2	V Kβ	0.0066	0.02	
Mn Kα1,2	Cr Kβ	0.0182	0.06	(Mn in chromite)
Fe Kα1,2	Mn Kβ	0.0272	0.09	(Fe in rhodonite)
Co Kα1,2	Fe Kβ	0.0337	0.14	(Co in kamacite)
Ni Kα1,2	Co Kβ	0.0384	0.18	
Cu Kα1,2	Ni Kβ	0.0417	0.22	

X-RAY OVERLAP AMONG RARE EARTH ELEMENTS

TABLE 002
X-RAY OVERLAP AMONG RARE EARTH ELEMENTS

Z	EL	LINE	LiFλ	KeV	Z	EL	LINE	LiFλ	KeV
57	La	$L\alpha_1$	2.6657	4.65					
58	Ce	"	2.5615	4.84					
59	Pr	"	2.4630	5.03	57	La	$L\beta_1$	2.4589	5.04
60	Nd	"	2.3704	5.23	58	Ce	"	2.3561	5.26
61	Pm	"	2.2822	5.43					
62	Sm	"	2.1998	5.64					
63	Eu	"	2.1209	5.85					
64	Gd	"	2.0468	6.06					
65	Tb	"	1.9765	6.27	62	Sm	$L\beta_1$	1.9981	6.20
66	Dy	"	1.9088	6.49	63	Eu	"	1.9203	6.46
67	Ho	"	1.8450	6.72	64	Gd	"	1.8468	6.71
68	Er	"	1.7843	6.95	65	Tb	"	1.7768	6.98
69	Tm	"	1.7268	7.18	66	Dy	"	1.7106	7.25
70	Yb	"	1.6719	7.41					
71	Lu	"	1.6195	7.65					